the journal of INDUSTRIAL ENGINEERING

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Basic Preparation for Industrial Engineering Curricula

by **R. H. McCARTHY**

Director of Plant Engineering, Plant Design and Construction Division, Western Electric Company, Inc.

INDUSTRY's mixed reactions to Industrial Engineering and confused interpretation of the term still reveal the youth of the profession even after its checkered growth for sixty years.

HISTORY

Frederick W. Taylor launched this branch of engineering by showing that the tools of analysis, design and control, when applied to industrial organization and work methods, could be as valuable to industry as were the new lathes, turbines, and motors developed by the mechanical and electrical engineers of his time. His school of thought included Carl Barth, Frank and Lillian Gilbreth, Henry Gantt, and a few others. By 1915 most of these had passed their heyday. What could have been a budding profession fell into the hands of the efficiency experts and promoters of wage payment plans and bonus systems. In the depression of the 1930's, a coined term "Technocracy" made things worse by displaying industrial inefficiencies and by the ill-timed projection of a push-button economy for all. The stature of the profession ranking with other branches of engineering almost came to an inglorious end.

The Taylor type of analysis of industrial wage systems, organization, materials handling, machining and plant arrangement took root in a few college faculties, notably at Cornell University and Pennsylvania State University, as worthwhile and suitable subjects for mechanical engineering curricula. What started as elective courses in industrial organization, time study, machine processes, plant design, cost analysis, and industrial safety, usually so broad as to be mostly topical and descriptive, grew to recognized departments in several engineering faculties of the 1920's. Then the mechanical engineering student could choose industrial organization as his major subject or option in the senior year or in the junior and senior years of college. The options appealed to a variety of students. Those who had had enough mathematics, formulæ and rigorous demonstrations liked the broader view of how a factory, or industrial organization of any kind for that matter, formed a productive unit. The subjects appealed to students headed toward sales of mechanical and electrical products who wanted enough engineering background to understand the product but not to become designers and developers. Then there were the students who obviously were to inherit the administration of a factory or service business. Students, who wanted more to make products than to design or experiment with them, found the option satisfying. Only a few students like Barnes, Morgensen, Stegmerten, Maynard and a growing number of college teachers were attracted to the possibilities of developing new theory and reliable practices for a field which as yet had small scientific foundations. Generally, the options acquired a reputation among students and some faculty as an easier way to an engineering degree.

It was true of the early courses in Industrial Engineering options that they required infrequent exercise of the mathematics already acquired for the more scientific of the basic engineering subjects. The courses had little theoretical content that could compare with the classic theories and demonstrations of mechanics, thermodynamics, electricity and metallurgy. Students did learn the terminology of industrial production and some practical analysis of industrial situations. The true measure of their training was the quality of their work in the basic engineering studies required of all students in the engineering college. Their work in basic courses might have progressed in an orderly way into the thermodynamics and mechanics of metal forming and cutting. Mathematics could have been applied to the layout or material handling problems of a factory. This observation is not to imply that these possibilities should have been discovered earlier, but to state that the approach of the Industrial Engineering courses laid aside much of the scientific background acquired by the students and instead came to these subjects from the practical side.

The reports of students and recruiters were not the only cause of industry's indifference to the Industrial Engineering graduate. A second cause, more significant than the character of the college courses, derived from the way industry was organized. Until approximately 1940, very few manufacturers had organized in a way which let an *engineering* organization take the responsibility for manufacturing methods and processes. The mechanical engineer went into the machine design organization or some

other department where mechanical engineers commonly worked. The electrical engineer likewise fitted into organizations and departments already existing in industry and consulting organizations. But into what organization should an Industrial Engineer go?

Not having forms of organizations fitted to use the training of Industrial Engineers, many concerns were at a loss as to how to use their training, and, therefore, avoided them. In reality, some of these concerns broke down the work of Industrial Engineers and scattered it throughout the organization. The master mechanic might have all responsibility for machinery selection, procurement and installation; the shop manager might have complete responsibility for deciding the exact steps by which his people should do their work. A scheduling and dispatching organization decided what products were to be made during any given period of production. A plant engineer not only maintained the buildings and their services but also decided how the buildings and machinery in them should be laid out and how the products should be handled through the steps of production. Still another organization, frequently in the comptroller's division, made time studies and established piece rates. And finally, the inspection organization had to be apart from all these, reporting as far "up the line" as possible to eliminate the possibility of being pressured into passing poor product.

The schools impressed students with the logic of consolidating all these various phases into a production planning and development unit that would make economic sense out of every physical step of manufacture and would fit the organization of human effort to this pattern —all as a kind of engineering—Industrial Engineering. Many industries have fallen in with this kind of organization, wanting all processes to be developed and planned in detail. They have departments of Industrial Engineers, production engineers, manufacturing engineers or of like title, who have real authority to control manufacturing processes. Others restrict the term Industrial Engineer to those who control piece rate and wage systems, and still others use the term for methods departments who are limited in responsibility and authority to control of motion patterns at the work location.

Current technologies of material processing compare to those of the 1920's as the machines of the 1920's compared to the machines of 1850. Some earlier problems of scientific management, such as time studies, are now sufficiently well formulated that *engineers* need no longer make the repetitive shop observations and convert them to wage rates. Quality control has grown since 1940 to a commonly accepted full-grown "tool"—just about in time to permit a level of quality in commercial products never before attempted, even though inspector's and worker's skills have changed but little. Methods of material handling, higher speeds of processing control data, simultaneous development, design and production of new products require concepts of an industry as a system that formerly could be handled by a few people intuitively but now must be explicitly delineated to all involved. The amount of capital required per unit of production has changed the relative importance of economic factors of production to the point where the utilization of capital weighs more heavily than the utilzation of direct human effort.

QUESTION

With this kind of history, what now should be the content of Industrial Engineering curricula? What are the core subjects that will supply the student and the economy he serves with a sound base for work immediately after college and later when college becomes only a four year period spent twenty years ago? A previous comment said that the group of studies called "industrial organization" fell originally into the bailiwick of the engineering profession, possibly because Frederick Taylor, a mechanical engineer, reported his work in the Transactions of the American Society of Mechanical Engineers. The studies have grown from the seeds he planted there, but they also appear in the schools of business administration and of industrial and labor relations and in economics departments. Regardless of which of the university schools are interested in industrial organization, is there a core of subject matter and discipline that has some natural coherence and upon which a specialized profession may be founded?

Discussion of the question of engineering curricula usually leads to agreement on a few objectives along the following lines:

1. Education should inculcate the habit of rigorous, complete analysis based upon logical, mathematical type test and demonstration within a body of recognized theory.
2. Education should give knowledge of and some practice with theories from the physical and chemical sciences.
3. Education should stimulate and open outlets for creativity.
4. Education should make the student aware of his responsibilities to society.

Usually there is little difficulty getting agreement on such a set of general objectives. The difficulty comes in translating them into specific step-by-step courses of study, form of training, and character of teaching personnel. The individual in a profession repeadedly uses a core of skills and experiences that can be grouped and classified as typical of his profession. That the student needs to become aware of the many avenues of influence bearing upon his chosen field of specialization should be evident. But some skills, experiences and knowledge recede into minor importance as the probability of their pertinence to his typical problems decreases. It is enough here to discuss what should be in the core. Students and graduates have strong individual convictions about answers to the question. So has industry; one might better say each industry has strong convictions about them. Any expression from industry as stated herein is intended to

be a statement directed to fellow engineers for comment and improvement as well as to the schools.

CORE DISCIPLINE—MATHEMATICS

Taylor and his disciples used scientific procedures as their means. Without them, their work would have had no promise of long life. For some twenty or thirty years, the promise was somewhat dimmed because their fields of interest had too little scientific attention, especially in the field of mathematical investigation. The plain time study, dispatch center, inspection, manufacturing lot size, study of metal machining got little beyond ordinary arithmetic and algebra. The writer was once chastened by an Industrial Engineering authority of thirty years ago for spending time on a mathematical basis for determining lot size, because it was obvious, the authority said, that the most economical lot size was no lot at all; i.e., continuous production.

This sounds a bit like proposing that a profession, in engineering at any rate, is not worthy of the name unless higher mathematics occurs all through its records. That is not the proposition. Rather, it is that until individuals having mentalities that are at home in mathematical thinking enter the area, suitable theoretical foundations are not laid for a science and its technologies and the possibilities of the area are not explored. Put affirmatively and specifically until the mathematics of statistics was applied to the control of quality, the development of inspection practices pointed toward refinement of gauges and repeated one hundred per cent inspections. Until the applicability of queueing theory and analog computers to programming were demonstrated, most emphasis was placed on string charts and other mechanisms for displaying the obvious data of shop schedule. Until the tools of mechanics, thermodynamics, and metallurgy were brought to machining practices, new developments stemmed from endless cut and try experiments. Until some well-equipped minds began to think of factory layouts and work sequences as problems in mathematics, factory plans were an empirical manipulation of templets.

Other examples can be brought to mind to show what an explosive effect mathematical thinking is having on Industrial Engineering. In the 1920's, the possibility of a mathematician becoming engrossed in the problems of Industrial Engineering and organization did not occur, at least on the engineering side of the campus. Now, excellent talent from undergraduates, graduates and faculty finds a wealth of mathematical problems in this kind of engineering. Not only has work in these new approaches increased the awareness of and competence with mathematics, but it greatly increased the inclination of the engineer to treat his problems in a refined quantitative way rather than with intuitive, qualitative solutions. Besides being a powerful tool for use on current problems, the study of mathematics provides a desirable discipline and a sharp instrument for enlarging the boundaries of the profession. Lest the significance of the term "desirable discipline" be left vague, let it be described as the ability to coordinate the factors of a situation and the habit of determining their combined effects in a logical way.

ENGLISH

After these comments about mathematics, the selection of other similarly fundamental subjects for engineering curricula comes with less certainty. Not to dwell needlessly upon the obvious, the study of language, its appreciation and use, must run throughout the entire curriculum. For some reason it was the tradition among engineers that language studies in any guise were frivolous, got nowhere and lacked the precision and force of their own chosen medium of expression. This underestimation led to carelessness in the universal medium of thought development and transfer. While impatient with language study, the student read and wrote laboriously, little comprehending that good writing takes the skill and care of a mathematical development to convey a thought concisely and accurately. Few engineering students would credit the poet with top skill in the field of concise and accurate expression. Such writing can not use the precise symbols of the engineer but must use words into whose formulation have gone centuries of history, emotion and expression. Engineers' impatience extended to legal language, little realizing the generations of human relationships which lawyers' documents aim to fix with minimum openings for the chicanery that has developed in the same generations. If respect for language study does not come from all engineering instructors, it will come hardly from one or two courses in literature or engineering composition.

PHYSICS AND CHEMISTRY

Probably the most difficult question about the Industrial Engineering curriculum deals with the amount of science that should be included. Curiously, the employer thinks of the new engineer as an investment for future value in administration as well as an immediate help in a specialized field of engineering. He knows that for the immediate job the engineer will have to be given considerable training by his own organization. Unless there is a direct transfer of school training, the employer would probably be much more positive in his desire to have in the new engineering employee a competence in accounting than a competence in thermodynamics, because the chances are that his Industrial Engineers will have to apply acounting far more often than thermodynamics. If, however, he were asked whether he would rather hire an engineer or an economics major in arts and sciences, doubtless he would choose the engineer—or was that twenty years ago?

Then, why does the Industrial Engineering student study thermodynamics at all, or for that matter, physics or chemistry? Are they studied as a safe procedure in the

first two years of engineering because a student might want to change to another engineering course without loss of standing after a year or two of college? Are they studied as excellent subject matter for the exercise of mathematics and of mental discipline, or as foundations for the engineering technologies studied in the following two or three years? As for the disciplinary value of the study of sciences, the engineering sciences hold no monopoly on requirements for scholarliness. Most would agree that while study of philosophy, literature, and music may appeal to different talents, their requirements for rigorous discipline can be quite as demanding as study of sciences.

Limits of time and ability make it impossible for an Industrial Engineer to be an expert in several fields of engineering science either in college or in later practice. Nevertheless, he will be called upon more than other engineers to recognize a wide variety of scientific situations and the kinds of engineering talent that can best be applied in the treatment of them. By the end of college he can have started on only the main roads through the sciences. How then can the need for greater breadth be reconciled with the need for thoroughness?

The processes and the products of industry embody countless applications of physics and chemistry. An understanding of these two sciences underlies any comprehensive understanding of the processes of manufacture. A working knowledge of the two is the price of admission for the Industrial Engineer to further scientific and engineering studies.

Returning to the question of how broad and how thorough studies should be, a strong urge exists to curtail the studies of several engineering technologies and to spend the time saved gaining greater competence in physics and chemistry. The thinking is that a thoroughly trained ability to use the tools of the several branches of physics and chemistry, especially physics, is more easily extended to engineering applications and will result in more fundamental solutions of problems than a knowledge of the numerous technologies of engineering applications. Distinguished students of physics and chemistry have demonstrated this to be entirely possible. This approach seems to be a refreshing relief from all the pressures of industry for "special" courses and a great simplification in the face of the bewildering accretion of engineering technologies available for inclusion in an engineering curriculum. The relatively new curriculum offered under the name engineering physics is a trial of this idea. In spite of these attractions of thoroughness and straightforwardness, if the Industrial Engineering curriculum were to lean entirely upon physics and chemistry for its scientific training, it would keep students too far away for too long from engineering practice.

ENGINEERING TECHNOLOGIES

Granting inclusion of the fundamental physics, chemistry, mathematics and language in all engineering curricula, the depth of their study must be reconciled with the time required for the study of their applications in the technologies of engineering. For about a half century, the amount of time devoted to the common general technologies and the amount devoted to the specialized technologies of a particular branch of engineering have filled most of the remainder of students' time. The common technologies are mechanics (including strength of materials, structures, kinematics and hydraulics), electricity, thermodynamics, metallurgy and material fabricating processes. The division of time among them varies from school to school and from time to time within a given school. Normally, the mechanical engineer, after studying the common technologies, pursues mechanics, thermodynamics and metallurgy more intensively. But now that Industrial Engineering has and is rapidly developing its own truly scientific technologies, such as quality control, data processing, operations research, at what stage should it depart from the mechanical engineering curriculum? As subject matter for developing the engineering attitude, it now needs less and less to rely upon other technologies.

Should the Industrial Engineering student who may well find himself in the chemical, mechanical, electrical, mining, construction or transportation industry try to get a bit of the engineering of each? Or should he get a good feel of what it takes to be thorough in one field? The easy statement is, industry wants the ability to think and practice in any engineering field. The employer wants most the ability to acquire, digest, and put to work information from any field and prefers thoroughness in a few subjects to slight acquaintance with many. This is worth far more than a slight knowledge of many technologies. Training in thoroughness cannot be acquired in the abstract, it must have subject matter on which to work; steam engines were not too bad, neither was the detailed structural design of a reinforced concrete factory structure. But if there is subject matter in the field of major interest that can be used to acquire this familiarity with and confidence in the use of his basic mathematics and science, much effort wastes away in dragging the student through a body of subject matter foreign to his interest and probable future needs. But which of the common technologies shall the Industrial Engineer's core of studies include (1)?

MECHANICS

The problem of forces and motion so completely pervades industrial processes and the design and selection of tools, machines and structures, that mechanics taught as an engineering technology becomes a basic requirement for Industrial Engineers. As one of the older classical sciences, it might appear to be one of the more static subjects having a well established content for the basic courses. This is not the case because so much new material develops in the province of the study that the single term mechanics almost loses its significance. Two examples

show the pressure upon engineering faculties to select the basics from a continually enlarging field so the student will have a sound foundation for progress and will not have wasted time on uninteresting manifestations. Forty years ago the theory required for dynamic balancing of rotating machinery was just being developed to meet the needs of higher rotating speeds of the masses. Now, men without the slightest knowledge of theory find the force of unbalance and the position for compensating weights for automobile wheels in five minutes at most any corner service station. Must today's students master this bit of theory in addition to those thought necessary forty years ago? Again, forty years ago, or was it twenty, there were the problems of water hammer in buildings and penstocks that were understood well enough, but then there were no oil and gas pipelines extending half way across the continent. Today the transient surges of hydraulic lines are in terms of resonance and electrical theory inverting the older practice of electrical engineers of resorting to hydraulic analogies. Should there then be in the mechanics book a chapter on piplines? It is in this continual searching for and study of new material for fundamental content and dropping of superfluous material that industry leans heavily upon the discretion of engineering faculties.

Industry has the corresponding problem of deciding how much of what is new in mechanics to incorporate in their products. Nearly every rational selection of material for processing, size of part, combination of parts, and prediction of wear under stress, behavior in motion, deformation by cutting or bending depends upon mechanics. While there is no way to prove it, it is probably safe to say that the largest single share of industrial cost reduction derives from better applications of this technology.

ELECTRICITY

After putting kinematics, statics, strength of materials and hydraulics under their master heading of mechanics, there are left of the usual mechanical and electrical curricula subjects wherein the student acquires his theoretical foundations, electricity, thermodynamics and metallurgy. Without detailed analysis of electricity and metallurgy, it is assumed that more electrical theory than normally appears in freshman and sophomore physics is needed by Industrial Engineers. They need not know only direct and alternating circuits as applied to power machinery but also as applied to "electronic" devices for power and other applications.

MATERIALS

With all the machining and forming of metals, with all the use of non-metallics, plastics, and natural fibers, the importance of understanding the internal make-up characteristics and capabilities of materials needs little emphasis.

THERMODYNAMICS

Of the conventional subjects of the mechanical engineering curriculum, thermodynamics is least needed by Industrial Engineers as a group. Obviously, if the Industrial Engineer works with a manufacturer of boilers, turbines, or their accessories, training in thermodynamics is desirable, but he can still do a very effective job in such manufacture with virtually no training beyond that of his sophomore physics. Few would deny the interest and training value it has for any student who is enthusiastic about engineering. The same can be said, however, for mechanics, electricity and metallurgy. A student who can handle these subjects has the scientific training needed to study thermodynamics should lack of it become a stumbling block.

CONCLUSION

The basics then upon which the Industrial Engineering technologies can be built are language, mathematics, physics, chemistry, mechanics, electricity, and metallurgy (or more broadly materials). Granting these, what specialized Industrial Engineering technologies should be added?

REFERENCE

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Minimum Average Fraction Inspected for a Continuous Sampling Plan

by **GEORGE J. RESNIKOFF**

Department of Industrial Engineering, Illinois Institute of Technology

CONTINUOUS sampling plans have been used with increasing frequency in such applications as acceptance sampling and the rectification of a production process, as well as in the verification of punch cards by the Bureau of Census.

The first published continuous sampling plan was the one now dubbed CSP-1, and presented in 1943 by H. F. Dodge, then of the Bell Laboratories (1). The plan applicable to characteristics subject to non-destructive testing on an attributes basis was intended for use in process inspection where it is desired to have assurance that the proportion of defective units in inspected product will be held down below some prescribed low value, called the Average Outgoing Quality Limit (AOQL). It presumes a continuous flow of consecutive articles, or consecutive lots. It is of particular interest for products manufactured by conveyor or other continuous process, or in situations where the formation of lots is not feasible.

The procedure of CSP-1, as given by Dodge, is as follows:

(a) At the outset, inspect 100% of the units consecutively as produced and continue such inspection until i units in succession are found clear of defects.

(b) When i units in succession are found clear of defects, discontinue 100% inspection, and inspect only a fraction f of the units, selecting individual sample units one at a time from the flow of product, in such a manner as to assure an unbiased sample.

(c) If a sample unit is found defective, revert immediately to a 100% inspection of succeeding units and continue until again i units in succession are found clear of defects, as in paragraph (a).

(d) Correct or replace with good units, all defective units found.

In the article in which Dodge introduced CSP-1 he gave a method of obtaining the parameters (f,i) which yield the prescribed AOQL. However this method yields a curve in the coordinates f and i so that one has a choice of an infinite number of pairs (f,i) all yielding the same value of AOQL.

The purpose of the present paper is to present the method of determining the parameters which yield the minimum average fraction inspected for a specified AOQL, for the continuous sampling plan CSP-1.

PROPERTIES OF CSP-1

Under the assumption that there is a constant probability p (called the Incoming Quality) that the process will produce a defective item, Dodge derived the Average Fraction Inspected function

$$F(p) = \frac{f}{f + (1-f)(1-p)^i}$$

If it is assumed that each observed defective is replaced by a nondefective then the Average Outgoing Quality function is

$$A(p) = P[1 - F(p)] = \frac{p(1-f)(1-p)^i}{f + (1-f)(1-p)^i}$$

The continuous function A(p) has a unique relative maximum, $\max_p A(p)$, called the Average Outgoing Quality Level (AOQL). In (1) Dodge gives graphs of contours in (f,i) for fixed values of AOQL $= A_o$. The pair of numbers (f,i) which yields a given value of A_o was obtained by eliminating p from the equations

$$\begin{cases} \mathrm{A}(p) = A_o \\ \dfrac{dA(p)}{dp} = 0 \end{cases}$$

However, no objective criterion was given for a specific choice of the parameters (f,i). For example, it is shown in (2) that for fixed A_o there is an explicit relationship

$$\text{(a)} \qquad f(i, A_o) = \frac{(1-A_o)^{i+1}}{(1-A_o)^{i+1} + A_o(1+i)^{1+i}i^{-i}}$$

Any pair of values $[i, f(i,A_o)]$ yields the same AOQL $= A_o$.

MINIMUM AVERAGE FRACTION INSPECTED FOR A SPECIFIED VALUE OF INCOMING QUALITY

In this article, the following criterion for the choice of a specified pair (f,i) is adopted: assume that Incoming Quality $p = p_o$; use the pair (f,i) for which AOQL $= A_o$ and for which $F(p_o)$ is a minimum.

To obtain these minimizing values, $f(p_o,A_o)$ and $i(p_o,A_o)$, we note that

$$F(p) = \frac{p - A(p)}{p} \text{ and since } F(p) > 0, \text{ then } A(p) < p$$

Therefore $F(p_o)$ will be a minimum when $A(p_o) = A_o$. Since $A(p) < p$, it follows that it is not possible to minimize $F(p_o)$ for $p_o \leq A_o$.

Solving the equations

$$\begin{cases} \dfrac{dA(p)}{dp} & p = p_o \\ A(p_o) & \end{cases} \begin{matrix} = 0 \\ = A_o \end{matrix}$$

for i and f leads to

$$i(p_o, A_o) = \frac{1 - p_o}{p_o - A_o}$$

$$\text{(b)} \quad f(p_o, A_o) = \frac{p_o - A_o}{p_o - A_o + A_o(1 - p_o)^{(1-p_o)/(A_o-p_o)}}$$

The value of the minimum Average Fraction Inspected obtainable at $p = p_o$ subject to AOQL $= A_o$ is

$$F(p_o, A_o) = \frac{p_o - A_o}{p_o}$$

It has been noted that, of necessity, $p_o > A_o$, i.e., it is not possible to minimize the Average Fraction Inspected for a value of Incoming Quality less than or equal to the AOQL. This may seem to limit the usefulness of this criterion for choosing the parameters (f,i), so some discussion of this point is in order.

One may look at the continuous sampling plan from two distinct points of view:

1. The Incoming Quality $p = p_o \leq$ AOQL, is considered satisfactory. However one uses the plan to insure, in case quality deteriorates at some later time, that the Average Outgoing Quality will not exceed a specified AOQL $= A_o \geq p_o$.

2. The continuous sampling plan is used as a screening device in order to reduce the Incoming Quality $p = p_o$, to some smaller Average Outgoing Quality less than or equal to p_o. This was Dodge's stated purpose in introducing the plan.

In the latter case the method of the present report should certainly be used since it accomplishes the objective with minimum inspection. In the former case no objective criterion for the choice of the pair (f,i) is available other than to make f as small as possible, consistent with psychological or administrative considerations.

To obtain i, for a specified value of Average Outgoing Quality equal to A_o, say, and for a specified value of Incoming Quality equal to P_o, say, one simply solves the equation.

$$i = \frac{1 - p_o}{p_o - A_o}$$

To obtain f one may use either of the equations (a) and (b), with the computed value of i inserted. If one desires to avoid the computation of f altogether one may obtain f from Dodge's graphs of contours of constant AOQL by using the computed i value as abscissa and then by reading off the corresponding ordinate f.

The graphs are available in Dodge's original article as well as in several well-known textbooks such as Bowker's and Lieberman's *Engineering Statistics* and Acheson J. Duncan's *Quality Control and Industrial Statistics.*

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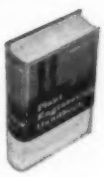

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The Effects of Auditory Visual Rhythmic Disturbances on Work Measurement Performance Rating

by **LOUIS E. DAVIS**

Department of Industrial Engineering, University of California, Berkeley

and **CHARLES SCHLEGEL**

Procter and Gamble Company, Sacramento, California

THIS STUDY, undertaken with experienced time study practitioners, reports experimentation directed at refinement and improvement of one of the instruments or methodologies of Industrial Engineering, that of time study.

Aside from historical production records, time study is the technique most widely used for establishing performance standards in business and industry. The Time Study procedure requires both timing of the elements of the operation and evaluating or rating of performance of the operator for a number of repetitions, to make an adequate sample. Performance rating is considered by many to be the key phase of the time study procedure and the study reported here (12) focuses on an important aspect of rating.

Performance rating has been defined (13) as "the process during which the time study man compares the performance pace or speed of the operator under observation with the observer's own concept of normal pace." This definition may be modified by noting that the observer's concept of "normal" is a translation through training of an accepted or agreed upon standard level of performance. The rating methods most widely used today are:

1. Effort Rating, described by Barnes (1, p. 364) and Presgrave (10, p. 154) in which observers compare the speed of pace observed in an operation against a standard level of speed or pace for this class of work as recorded in a reference or training film. The standard level of pace for the relevant class of work was previously interpreted from the agreed upon or accepted general standard level of performance pace or speed.

2. Objective Rating described by Mundel (6, p. 370) and Nadler (8, p. 379) in which observers compare speed or pace observed in an operation against the level of speed or pace of a standard activity recorded in a film. In addition the observer identifies the physical differences between the observed and the standard activities as "difficulties" of the job. Tables of "job difficulties" provide adjustment factors to be added to the initial rating.

Both methods are partially subjective albeit in different dimensions. They depend upon the use of films to train observers in the skills of pace identification and comparison. Standard level or bench mark paces or speeds are recorded on films for reference and training as are variations of these tempos along particular associated scales. Films are also used for testing rating proficiency (1, p. 376) and for retraining of practitioners. Training practitioners to make accurate and consistent rating judgments is one of the central problems in the use of performance rating. So the use of films in training becomes central to effective time study practice.

It must be explicitly understood that the use of films is based on the assumption that films and actual operations present the same perceptual stimuli to the rater. This assumption is not being validated here, although there is disagreement on it at present. A study by Margolen (4) supports the assumption and two others, one by Nadler (7) and one by McGuire (5) do not. In addition, rating training appears to be based on the theory that rating perception is a function of past experience and that perception takes place in an acquired frame of reference. If Hastorf's (2) notions about perception are correct, then the present method of training using repeated experiences of rating activities in relation to a benchmark, seems to be an adequate training approach for the rating process which consists of perception and comparison.

The training of time study practitioners is most commonly achieved by the use of silent films depicting a single or a number of bench mark activities. One of the most widely used film series is that developed by the Society for the Advancement of Management, popularly called the SAM films. As already indicated, a question arises as to whether these presently used silent films adequately simulate the work situation, particularly since studies have shown that the presence of auditory and visual stimuli affect the estimation of time intervals and the perception of rhythm patterns (3) (9).

PURPOSE AND OBJECTIVES

The purpose of the study reported here is to examine the influence of the working environment on the time study practitioner's execution of the rating task, given

prior rating training by commonly used training films. The specific objectives of the study were:

1. To investigate the effectiveness of two types of performance rating training, both using films, in providing time study practitioners with the learning needed to make adequate rating judgments when rhythmic auditory and visual background disturbances external to the work task are present.
2. To investigate the effects of rhythmic auditory and visual background disturbances external to the work task on the rating judgments made by experienced time study practitioners.

To carry out the purposes of the study, groups of matched, experienced time study observers were retrained. One group was trained using conventional SAM films. The other group used a special color, sound training film designed to simulate the work environment by having rhythmic auditory and visual background disturbances. In addition, a sound, color, rating test film was made which contained rhythmic auditory and visual background disturbances to simulate the work environment. The ratings made of the test film activities were analyzed to determine:

1. The effectiveness of type of training.
2. Whether specific disturbances had significantly different effects on rating judgments and whether these effects differed at various work paces or speeds.

The 63 subjects who participated in the experiment came from four large West Coast establishments. They were seasoned time study practitioners with an average of 4.33 years of experience ranging from ½ to 22½ years.

DESIGN OF EXPERIMENT

The study was carried out in the following stages:

1. Pretest: The 63 subjects were given the SAM films ABC and VWX in which they evaluated 24 paces or speeds.
2. Group Formation: Using a weighted point score for various degrees of rating accuracy in the pretest, the subjects were divided into 3 groups, A, B, C, of matched subjects.
3. Training:
   a. Group A was given training with SAM films.
   b. Group B was given training with a special color training film with coordinated sound, containing auditory and visual background disturbances.
   c. Group C was the control group and received no training.
4. Final Test: All groups rated a sound, color test film containing an activity performed at different paces with various rhythmic auditory and visual disturbances.

DESIGN OF STATISTICAL ANALYSES

With the data to be obtained from the test film an analysis of variance design was used to investigate the significance, if any, of background rhythmic auditory and visual disturbances and training effects. The planned experiment formed a two-way layout with replications, each pace being analyzed separately. The analysis of variance layout is represented by:

$i = 1, \ldots, I$ columns
$j = 1, \ldots, J$ rows
$k = 1, \ldots, K$ replicates in each cell

which were assumed to be described by the model

$$\Omega: Y_{ijk} = \mu + T_i + D_j + \delta_{ij} + \epsilon_{ijk}$$

where

Y_{ijk} is the rating of the kth subject on the jth disturbance scene after having the ith training.
μ represents the grand mean of the ratings of all subjects under each combination of training and disturbance.
T_i represents training effects (column effects).
D_j represents disturbance effects (row effects).
δ_{ij} represents the interaction effects, i.e. any variations which may be peculiar to a particular combination of training and disturbance.
ϵ_{ijk} represents experimental error effects and are assumed to be independently distributed $N(O, \sigma^2)$ and the indices can assume the following values:
$i = 1, \cdots I$; indicates the type of training. To facilitate the interpretation of results the indices $i = 1, 2,$ or 3 may be used interchangeably with the symbols denoting training types SAM, Special, or Control, respectively.
$I = 3$
$j = 1, \cdots J$; indicates the type of disturbance. To facilitate the interpretation of the results the indices $j = 1, 2, \cdots 15$ may be used interchangeably with the symbols denoting disturbance types $0.5A$, $0.8A$, $\cdots$ or $1.5V$, respectively.
$J = 15$
$k = 1, \cdots K$; indicates the number of subjects.
$K = 21$

Under the model, Ω, the following three hypotheses were to be tested using the same experimental data:

$$H_1: \mu + T_i = p \qquad H_2: \mu + D_j = p \qquad H_3: \delta_{ij} = 0$$

where p is the work pace or speed.

If significance were found, Scheffé's method of multiple comparisons (11) was to be used to determine which specific effects led to the significance.

The analysis of variance requires performing three tests on the same data. This reduces the confidence with which joint statements concerning the significance of parameters may be made and the confidence level is no less than $1 - 3\alpha$, when α = significance level for the tests. In order to examine the comprehensive picture, a single F test will be made at the 5% level of confidence to test the hypothesis,

$$H_4: \mu - p + T_i + D_j + \delta_{ij} = 0,$$

where p is the work pace and all the other parameters are as previously defined.

If significance were found, Scheffé's method of multiple comparisons (11) was to be used. The power curves for

all tests were to be determined to aid in evaluating the results. Therefore the probability of making a Type II error (failing to reject a false hypothesis) when accepting the null hypothesis can be estimated.

METHOD

INSTRUMENT CONSTRUCTION

To perform the experiment a special training film and a test film were made. The special training film, which was used to train one group of subjects (B), was a 16 mm. silent, color film containing the activities "Deal Cards," "Transport Marbles," "Toss Blocks," and "Pegboard." Each of the four activities was shown at 16 work paces or speeds, of which two had no background disturbance, four had auditory, four had visual, and six had both rhythmic auditory and visual background disturbances. The auditory disturbances were introduced by coordinated use of a tape recorder. A total of 64 scenes was available on the training film.

A test film simulating a working environment containing rhythmic auditory and visual background disturbances provided the means of evaluating the effects of these on rating ability. This 16 mm. sound, color film contained three paces or speeds of the manual activity "Transport Marbles." The three activity paces were 80%, 100%, and 120%, each of which appeared without disturbances. Each pace was also shown with seven auditory

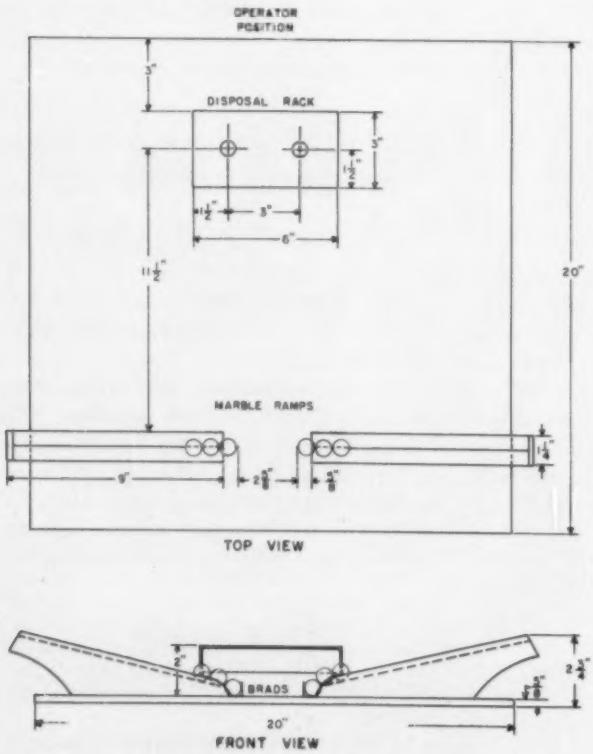

Fig. 1. Test Film: Workplace Layout.

Fig. 2. Test Film: Transport Marbles with Visual Background Disturbance.

and then with seven visual background disturbances, making 42 scenes. In no scene were auditory and visual disturbances introduced together. Both the auditory and the visual background disturbances simulated the rhythmic action of a punch press at 50%, 80%, 90%, 100%, 110%, 120%, and 150% of each of the work paces. Figure 1 shows the work place layout and Figure 2 shows the work area with the simulated punch press for a visual disturbance scene. Forty-five test scenes were presented in the film in stratified random order. In addition, the first scene, at 100% (without disturbances) was announced to the subjects as a bench mark.

PROCEDURE

Pretest and Matched Subject Group Formation

In the first step of the study a rating pre-test was administered to each subject, consisting of judging 24 paces on SAM rating films ABC and VWX. Points were allotted for the accuracy of each rating judgment with respect to actual pace, thus directly evaluating rating accuracy and indirectly evaluating consistency. A weighted-point score was obtained for each subject by summing the points assigned for the 24 ratings. Subjects were then ranked according to their weighted-point scores and then divided into "q" strata with the first three subjects in the first stratum, the next three in the second stratum, etc. Taking each of the "q" strata in turn, subjects were randomly assigned to form three groups of 21 subjects each. Group A received the standard SAM training, Group B was given the special training film, and Group C as the control group received no training.

Training

Groups A and B were trained in the same manner with the subjects being instructed as to what activities (and disturbances for Group B) would appear on the films, as well as having the benchmark pace for each activity identified. The subjects then rated the remaining 12 scenes on each of 4 reels making a total of 48 rating scenes. After each 12 scenes the subjects plotted their ratings versus actual paces and scored their performance

using the weighted-point scoring method. The subjects followed their own progress and the weighted-point scores provided high interest during the training period.

Final Test

The members of all three groups were given the previously described test film at the same time. The activity, Transport Marbles, and disturbances were described and the pace of the benchmark scene was then provided. The subjects rated the pace or speed shown in the remaining 45 scenes of the test film.

RESULTS

Table 1 gives the results of the analyses of variance in which each of the three work paces was analyzed separately. For all three work paces the F test associated with H_1, H_2, H_3 indicates that disturbance and training were both significant while interaction was not. Further examination of the data was necessary to determine causes.

TABLE 1

Analysis of Variance

Work Pace	Source of Variance	df	M.S.	F_{obs}
84	Disturbance (D)	14	588.50	7.94*
	Training (T)	2	3256.00	43.92*
	Interaction ($D \times T$)	28	62.18	0.84
	Error	900	74.14	
	Total	944		
105	Disturbance (D)	14	494.43	6.01*
	Training (T)	2	1276.00	15.52*
	Interaction ($D \times T$)	28	33.71	0.41
	Error	900	82.22	
	Total	944		
126	Disturbance (D)	14	590.29	5.90*
	Training (T)	2	572.00	5.71*
	Interaction ($D \times T$)	28	41.18	0.41
	Error	900	100.11	
	Total	944		

* Significant at 0.05 level (although the 0.05 level was chosen in statistical design, these values are beyond the 0.005 cut-off).

EXAMINATION OF SIGNIFICANT EFFECTS

Scheffé's method of multiple comparisons (11) makes it possible to determine which specific training and disturbance effects caused the significance found with the F test. Proper interpretations using this technique must be made with the aid of the power functions of the various F tests. The power of a test, therefore, is given with the results of the test.

Tables 2 and 3 give results of comparisons made to determine a. which training effects led to significance in the F test and b. existence of significant differences between pairs of trainings.

In Table 2 it is seen that none of the training groups performed well at the low pace ($p = 84$). The results shown in Table 3 indicate that at the low pace ($p = 84$) the effect of special training was significantly different from both the SAM and no-training (power, $\beta = 0.94$). At the other paces the effects of training were mixed. Statements made about comparisons of training effects at the higher paces cannot be made strongly because of the relatively low power of the tests. A priori estimates that the special training would provide a better preparation for practitioners was not supported.

TABLE 2

Results of Comparisons of Training Group Means and Paces
Hypothesis Tested: $(\mu + T_i) = p$ for $i = 1, 2, 3$

Work Pace, p	Training Group, i	Experimental Estimates of $\hat{\mu} + \hat{T}_i$	Result of Test*	Power of Test, β**
84	SAM film	86.8	Rejected	0.94
84	Special film	91.9	Rejected	0.94
84	Control	86.0	Rejected	0.94
105	SAM film	104.4	Accepted	0.66
105	Special film	108.3	Rejected	0.66
105	Control	107.4	Rejected	0.66
126	SAM film	123.4	Rejected	0.52
126	Special film	123.9	Rejected	0.52
126	Control	125.9	Accepted	0.52

* Throughout all tests, significance level = 0.05.
** Power calculated on basis of estimated values.

Tables 4, 5, and 6 give the results of comparisons made to determine a. which disturbance effects contributed to significance in the F test, b. the existence of significant differences between pairs of disturbances, and c. the existence of significant differences between collections of disturbances.

Table 4 indicates the disturbances whose effects were such that they caused a mean rating significantly different from each of the work paces. At the low pace ($p = 84$) one visual disturbance mean (.5V) and four auditory disturbance means were significant. Only one disturbance mean (1.0A) was significantly different from work pace 105. At the high pace ($p = 125$) only the no-disturbance mean was significant, however the power of the test is not high. Figure 3 shows the mean performance ratings as the different disturbances were introduced at each test work pace.

Table 5 gives the combinations of disturbances that were significantly different. At the low pace ($p = 84$) there

TABLE 3

Results of Comparisons of Training Effects
Hypothesis Tested: $T_a = T_b$ (Equality of Training Pairs)

Work Pace, p	Training Pairs	Experimental Estimates of Pairs; $\hat{T}_a$, $\hat{T}_b$	Result of Test*	Power of Test, β**
84	Special, SAM	+3.7, −1.4	Rejected	0.94
84	Special, Control	+3.7, −2.2	Rejected	0.94
84	SAM, Control	−1.4, −2.2	Accepted	0.94
105	Special, SAM	+1.6, −2.3	Rejected	0.66
105	Special, Control	+1.6, +0.7	Accepted	0.66
105	SAM, Control	−2.3, +0.7	Rejected	0.66
126	Special, SAM	−0.5, −1.0	Accepted	0.52
126	Special, Control	−0.5, +1.5	Accepted	0.52
126	SAM, Control	−1.0, +1.5	Rejected	0.52

* Throughout all tests significance level = 0.05.
** Power calculated on basis of estimated values.

TABLE 4

Results of Comparisons of Disturbance Type Means and Work Pace
Hypothesis Tested: $\mu + D_j = p$

Work Pace, p	*Indices* of Accepted Hypotheses***	*Corresponding Experimental Estimates,* $\hat{\mu}+\hat{D}_j$	*Indices of Rejected Hypotheses*	*Corresponding Experimental Estimates,* $\hat{\mu}+\hat{D}_j$
84	0, 0.8A, 1.0A, 1.1A,	85.7, 82.7, 86.5, 86.1,	0.5A, 0.9A, 1.2A,	90.1, 91.4, 93.1,
Power of test,	0.8V, 0.9V, 1.0V,	84.9, 87.8, 87.6,	1.5A, 0.5V	90.2, 93.7
$\beta = 0.80$	1.1V, 1.2V, 1.5V	89.3, 86.6, 89.0		
105	0, 0.5A, 0.8A, 0.9A	107.0, 105.2, 101.2, 105.9,	1.0A	113.1
$\beta = 0.50$	1.1A, 1.2A, 1.5A 0.5V, 0.8V, 0.9V, 1.0V, 1.1V, 1.2V, 1.5V	103.9, 104.8, 110.6, 106.3, 108.3, 109.2, 105.4, 105.8 106.5, 106.8		
126	0.5A, 0.8A, 0.9A, 1.0A, 1.1A, 1.2A,	123.3, 122.0, 130.3, 129.7,	0	119.3
$\beta = 0.46$	1.5A, 0.5V, 0.8V, 0.9V, 1.0V, 1.1V, 1.2V, 1.5V	125.1, 126.1, 120.9, 123.2, 124.3, 122.8, 127.3, 123.5, 125.7, 122.3		

* Index 0.8A is Auditory disturbance at 0.8 rate of work pace, etc.
** Throughout all tests, significance level = 0.05.

were six such combinations, including one significantly different from the no-disturbance effect. At $p = 105$ there were four significantly different combinations, while at the high pace ($p = 125$) three combinations of disturbance effects were significantly different and two of these from the no-disturbance effect.

As seen in Table 6, the mean value of auditory disturbance effects is not significantly different from the mean value of visual disturbance effects. Neither the mean values of the auditory nor of the visual disturbance effects are significantly different from the values of the no-disturbance effects. These apply at all three work paces.

TABLE 5

Results of Comparisons of Disturbance Effects
Hypothesis Tested: $D_c = D_d$ *(Equality of Disturbance Pairs)*

Work pace, p	*Disturbance Pairs*	*Experimental Estimates of Pairs,* $\hat{D}_c$, $\hat{D}_d$	*Result of Test****	*Power of Test, β***
84	$D_{.5V}$, D_0	+5.5, −2.5	Rejected	0.80
84	$D_{.5V}$, $D_{.8V}$	+5.5, −3.3	Rejected	0.80
84	$D_{.5V}$, $D_{.8A}$	+5.5, −5.5	Rejected	0.80
84	$D_{1.2A}$, $D_{.8V}$	+4.9, −3.3	Rejected	0.80
84	$D_{1.2A}$, $D_{.8A}$	+4.9, −5.5	Rejected	0.80
84	$D_{.9A}$, $D_{.8A}$	+3.2, −5.5	Rejected	0.80
105	$D_{1.0A}$, $D_{1.2A}$	+6.4, −1.9	Rejected	0.50
105	$D_{1.0A}$, $D_{1.1A}$	+6.4, −2.8	Rejected	0.50
105	$D_{1.0A}$, $D_{.8A}$	+6.4, −5.5	Rejected	0.50
105	$D_{1.5A}$, $D_{.8A}$	+3.9, −5.5	Rejected	0.50
126	$D_{.9A}$, $D_{1.5A}$	+5.9, −3.5	Rejected	0.46
126	$D_{.9A}$, D_0	+5.9, −5.1	Rejected	0.46
126	$D_{1.0A}$, D_0	+5.3, −5.1	Rejected	0.46

* Throughout all tests, significance level = 0.05.
** Power, β, calculated on basis of estimated values.
*** All other combinations of pairs D_c, D_d for each pace were Accepted at 0.05 level.

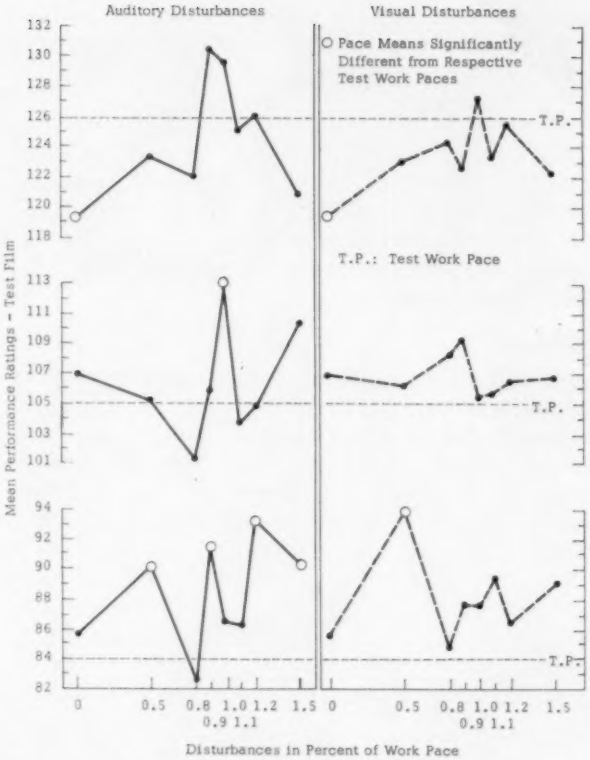
Auditory Disturbances
Visual Disturbances
Pace Means Significantly Different from Respective Test Work Paces
T.P.
T.P.: Test Work Pace
Mean Performance Ratings - Test Film
Disturbances in Percent of Work Pace

FIG. 3. Mean Performance Ratings for Different Disturbances at Each Test Work Pace.

COMPREHENSIVE ANALYSES OF VARIANCE

A comprehensive over all analysis, which is a test for homogeneity of all ratings, was undertaken so that joint statements about the significance of all parameters could be made with known confidence, recalling that this was not possible with the previously discussed analyses. The models used to make the analysis were:

$$\Omega : Y_{ijk} = \mu + T_i + D_j + \delta_{ij} + \epsilon_{ijk}$$

$$\omega : Y_{ijk} = p + \epsilon_{ijk}$$

where the parameters are as previously defined.

The hypothesis tested was

$$H_4 : \mu - p + T_i + D_j + \delta_{ij} = 0$$

First, testing for significance of all effects simultaneously by use of the F test, the hypothesis is rejected for there was significance at 0.05 level at all work paces. The results for each pace were:

$$F_{84} = 10.11 \qquad F_{105} = 3.55 \qquad F_{126} = 2.89$$

Scheffé's method of multiple comparisons was then used to compare any combinations of parameters and to make a joint statement with known confidence. The results of these comparisons are shown in Table 7. If desired, all parameters can be obtained from Tables 2 through 6 by

TABLE 6

Results of Comparisons of Auditory and Visual Effects

Hypotheses: $\frac{1}{7}\sum_{\text{Aud}} D_i - \frac{1}{7}\sum_{\text{Vis}} D_i = 0$			$\frac{1}{7}\sum_{\text{Aud}} D_i - D_0 = 0$		$\frac{1}{7}\sum_{\text{Vis}} D_i - D_0 = 0$	
Work Pace, p	Experimental Estimates	Result of Test*,**	Experimental Estimates	Result of Test*,**	Experimental Estimates	Result of Test*,**
84	.41 − .21	Accepted	.41 + 2.5	Accepted	.21 + 2.5	Accepted
105	− .31 − .20	Accepted	− .31 − 0.3	Accepted	.20 − 0.3	Accepted
126	.87 + .24	Accepted	.87 + .73	Accepted	− .24 + .73	Accepted

* Throughout all tests, significance level = 0.05.
** Power of Test, $\beta = 0.80$ for $p = 84$, 0.50 for $p = 105$, 0.46 for $p = 126$.
Power calculated on basis of estimated values.

arithmetic manipulations using the following grand mean value estimates:

$$p = 84, \hat{\mu} = 88.2; \; p = 105, \hat{\mu} = 106.7; \; p = 126, \hat{\mu} = 124.4$$

A note regarding the results shown in Table 7 is indicated. The apparent discrepancies in those parameters concluded to be significant, shown in Table 2 through 6, as compared to those in Table 7 are due to the fact that in the former, the tests were designed to consider the collective row (column) effects separately and hence were more efficient in estimating the respective parameters. Since the comprehensive test combines all effects into one test at the 5% significance level, fewer significant parameters are to be expected. Alternatively, the net effect may be expressed by the fact that in the former case the overall significance level is known only to be less than 15% and in the latter case is equal to 5%.

Very few of the comparisons investigated showed significance. This may be the consequence of the comprehensive test, as indicated above. At pace 84, the mean of the special training was found to be significantly different from the pace. Also for pace 84, 1.2A and .5V disturbance effects means were significantly different from the pace. It is seen from Table 7 that no other effect was found to be significantly different from any other effect. This apparent disparity can be explained as follows. The latter result indicates that the estimates of the effects were distributed closely together. However some of the effects, namely those stated, were estimated to be far enough from the standard to be significant.

CONCLUSIONS

This study was designed to examine the effects of a. training by means of conventional versus special rating films, and b. background disturbances on performance rating effectiveness of experienced time study practi-

TABLE 7

Results of Comparisons from Comprehensive Analysis of Variance

	Pace, p *Power of Test, β***	84 0.64	105 0.36	126 0.31
Hypothesis	*Comparison*	*Result of test**	*Result of test**	*Result of test**
$\mu + T_i = p$	$\mu + T_{\text{sam}} = p$	Accepted	Accepted	Accepted
$\mu + T_i = p$	$\mu + T_{\text{special}} = p$	Rejected		
$\mu + T_i = p$	$\mu + T_{\text{control}} = p$	Accepted		
$T_a = T_b$	$T_{\text{spec}} = T_{\text{sam}}$	Accepted		
$T_a = T_b$	$T_{\text{spec}} = T_{\text{control}}$	Accepted		
$T_a = T_b$	$T_{\text{sam}} = T_{\text{control}}$	Accepted		
$\mu + D_i = p$	$\mu + D_{1.2A} = p$	Rejected		
$\mu + D_i = p$	$\mu + D_{.5V} = p$	Rejected		
$\mu + D_i = p$	All remaining D_i	Accepted		
$D_c = D_d$	All combinations			
$C_{ac} = D_{bd}$***	All combinations			
$\frac{1}{7}\sum_{\text{Aud}} C_{ij} = \frac{1}{7}\sum_{\text{Vis}} C_{ij}$	All combinations			
$\frac{1}{7}\sum_{\text{Aud}} D_i = \frac{1}{7}\sum_{\text{Vis}} D_j$				
$\frac{1}{7}\sum_{\text{Aud}} D_i = D_0$				
$\frac{1}{7}\sum_{\text{Vis}} D_j = D_0$				

* Through all tests, significance level = 0.05.
** Power of test calculated on basis of estimated values.
*** $C_{ij} = T_i + D_j + \delta_{ij}$.

tioners. Therefore it might be well to indicate that no conclusions are stated regarding the ability of the time study practitioners to carry out performance rating because variability of individual raters was not examined.

EFFECTIVENESS OF TRAINING BASED ON TWO-WAY CLASSIFICATION ANALYSES OF VARIANCE

The following conclusions are based upon comparisons for significant differences between training effects.

1. Conventional (SAM) training enabled subjects to rate performance more effectively under disturbance conditions than did the special training which was intended to provide experience under disturbance conditions. For the length of training provided, the SAM training may well have reinforced similar prior training of the subjects, who were experienced time study practitioners, while there may have been a negative transfer between the special and prior (conventional) training. It is intended to conduct a similar experiment with subjects who have not been previously trained in performance rating to provide further insights into the effects of training with background disturbances on rating effectiveness.

2. Conventional (SAM) training, which may have reinforced prior similar training of experienced practitioners (this may be viewed as retraining), was beneficial as a method of preparing observers to rate work paces close to "normal" or "standard" under background disturbance conditions. However, the training had no effect on rating low pace (compared with control group) and a negative effect on rating high work pace under disturbance conditions.

3. Conventionally (SAM) trained (or retrained) practitioners rating under background disturbance conditions performed according to a priori estimates formed from empirical evidence which indicates that rating accuracy decreases as observed work paces depart from "normal" or "standard." Also, support was added to prior empirical evidence that such training provides a tendency toward "normalization" in rating, by which is meant, under-evaluating superior performance paces and over-evaluating inferior performance paces.

EFFECTS OF RHYTHMIC AUDITORY AND VISUAL DISTURBANCES BASED ON TWO-WAY CLASSIFICATION ANALYSES OF VARIANCE

The following conclusions are based upon comparisons for significant differences between background disturbance effects. (See Tables 5 and 6)

1. To the extent that the test film represents actual work environment, it may be concluded that trained practitioners (based upon the particular group in this study) would not be affected in their rating judgments by rhythmic background disturbances existing in the work environment. This conclusion is based upon the results reported in Table 5 which showed that only one disturbance effect ($D_{0.87}$) was significantly different from the disturbance-free rating at work pace 84; no disturbance effect was significantly different from the disturbance-free rating at work pace 105, and two disturbance effects ($D_{0.84}$ and $D_{1.64}$) were significantly different from the disturbance-free rating at work-pace 126.

2. Based upon the results reported in Table 6, it may be concluded that the presence of rhythmic auditory and visual background disturbances does not significantly affect performance rating as compared with rating performance under disturbance-free conditions. This conclusion is not made with a great deal of confidence, for the power of the significance tests for the three test work paces was 0.80, 0.50, and 0.46. Further investigation seems to be indicated.

3. There were no specific types of disturbances which, at all three work paces on the test film, caused the activity to be rated with a mean rating different rom the work pace. Thus, it may be concluded that no single relative pace of visual or auditory background disturbance has a significantly different disturbing effect from any other.

4. The relative disturbing effects of auditory and visual disturbances are not easily interpreted. The mean effect of auditory disturbances was not significantly different from the mean effect of visual disturbances. However, of the six disturbance situations where the activity received a mean rating significantly different from the work pace, only one was a visual disturbance.

CONCLUSIONS BASED ON ANALYSIS OF VARIANCE

1. Only two disturbance means were found to be significantly different from the work pace and these were at the low pace. Also no combination of disturbances provided any significantly different effects. This would indicate that background disturbances that are present in the work environment would tend to cause little adverse effect on a practitioner's rating judgments. However, the nature of the comprehensive test is such that it is less restricting and hence yields less information on the significant parameters.

2. If the test film represents the reality of the work environment, then it can be concluded that any performance rating training by means of films (the control group as well as the two training groups had histories of prior conventional training using SAM or similar films) seems to be adequate preparation for practitioners to rate activities under conditions where background disturbances are present. The type of training received (with or without disturbances in the training films) would appear to make no difference and the presence of disturbances in the work environment would appear to cause no significant adverse effects.

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The Role of the Industrial Engineer in the Emerging Profession of Management[1]

by **KENNETH W. OLM**

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WE ALL RECOGNIZE that the United States has developed into the leading industrial nation of the world —that the United States economy is truly an economy of abundance with a standard of living unmatched (with a possible minor exception or two) throughout the world. Our gross national product is now close to the half-trillion dollar level, and, except for the effects of the steel industry shutdown, our economy would have exceeded that level this past year. An intriguing question for all thinking people, here and abroad, is "why?" To what factors do we attribute this wonderful and amazing situation? I think it specious to attribute this to God in that He would just as likely provide for the rest of the world as well.

Many factors contributed to our achievements. Plentiful resources, large land area, stable government, and so on. Two factors which I regard as vital to a dynamic, increasingly productive economy are technological developments and professional management.

These two factors are intimately related in the sense that the first is encouraged and made to flower by the support and promotion of an enlightened professional management.

The Industrial Engineer is vitally concerned with both. To technological development he has made an important contribution, and to professional management he is rapidly assuming an important role.

While we have enjoyed tremendous material benefits in the past, we still have far to go to realize our true potential, let alone to maintain the status quo.

PRODUCTIVITY

Many thoughtful persons maintain that the most crucial problem facing management today is productivity. This is as much a social problem as it is a technical problem. The current tenor of our labor-management bargaining certainly reinforces this observation.

It is not the application of pure science alone which will help solve this problem. Purely technical competence alone is insufficient. Professional competence in understanding social responsibilities, in dealing with human relations problems, is necessary as well to deal effectively with productivity.

Most of us recognize that the primary obligation of management of an enterprise is to operate in such a manner as to provide a service to the public so that it can earn a profit. We all recognize that a business must be productive and profitable if it is to continue to produce goods and provide jobs.

We are faced, then, with these questions:

1. What does the manager do to contribute to productivity—and thus to the good of our economy?
2. How does a person develop into a professional manager? What is a professional manager? Can we recognize one when we see one?
3. Where does Industrial Engineering fit into this question?
4. What type of training is desirable for the Industrial Engineer to further his possible career in management?

MANAGEMENT

"Management is the function of executive leadership (1)." It is a universal function because no organization can accomplish its objective effectively and economically without leadership.

The basic functions of management may be classified into these activities: creative planning, organizing, directing and controlling. All executives perform these functions to some extent, whether they are administrative or operative executives, line or staff.

Many excellent discussions of management and administration are available to the interested reader (1) (2) (3) (7). Chester Barnard's classic book, *The Functions of the Executive,* is certainly worthy of your time. His development of the subject "willingness to cooperate" is a most interesting approach to establishing the necessity for dynamic leadership as an essential executive function. He has established from his experience that a "purpose alone does not incite cooperative activity unless it is accepted by those whose efforts will constitute the organization. Thus, the inculcation of belief in the real existence of a common purpose is an essential executive function." Such can be accomplished only by dynamic leadership.

Without common purpose, cooperation and coordination of effort are lacking, and the result is obvious to all. Lack of time prevents my discussing the other functions of the executive so interestingly presented by Barnard.

Crawford Greenewalt, President of Du Pont, presented his views on management in a brief but interesting article (5). He stated that "business (management) as a profes-

[1] Based upon a presentation to the San Antonio Chapter of the American Institute of Industrial Engineers, October 19, 1959.

sion is coming of age, and its members can stand before the world as practitioners of a difficult and complex art, without which the world would be the poorer. And if you have lingering doubts as to the place of executive management, ask yourself what your own companies would be today if the wrong decision had been made at the crucial moment."

He went on to say, "Prestige for this new profession will come, I know. It will come as people begin to understand and appreciate the contribution of business to the social, cultural, and the spiritual advancement of America."

PROFESSION

Let us consider briefly, "What is a profession?" Approaching this question from the point of view of the attributes of a profession and its practitioners, we come to the following:

1. It must satisfy an indispensable and beneficial social need.
2. Its work must require the exercise of discretion and judgment.
3. It is a type of activity conducted upon a high intellectual plane (where the knowledge and skills used are not the common possessions of the general public, beyond the power of the public to judge or to regulate, but the results of a special discipline and practice).
4. It must have group consciousness.
5. It should have public and possibly legal recognition.

You may very well question whether all or most of these apply to the practice of business management. Many do, I believe.

How about attributes of professional practitioners?

1. They must have a service motive (thus financial return is not to be the chief measure of success).
2. They must recognize their obligations to society and to other practitioners by living up to accepted and established codes of ethics.
3. They must assume relations of confidence and accept individual responsibility.
4. They must advance ideals and practice for the benefit of the profession.

I am certain that again you may question whether most of these attributes apply. But certainly you will recognize that they are becoming increasingly common attributes of large numbers of management personnel as the desire for professional competence becomes stronger and more highly developed.

The trend toward the development of management as a profession may be attributed mainly to a very fundamental change in business which has had widespread socio-economic effects. (I need not stress the impetus which Frederick Taylor's writings and philosophy provided to this development.)

No longer is management primarily a right or prerogative of ownership. The development of large-scale enterprise, the popularity of the corporate form of organization, and the development of high level income and estate taxes have all had a profound effect on the development of professional managers.

The entrepreneur, in the classical sense, is still with us, but think how much less important he is today, relatively, than just fifty years ago, or even just twenty years ago.

In most corporations of any size, and in all public enterprise, the manager is an employee hired for his competence, maintaining his position by virtue of his ability to perform. There are more skills and techniques to master, more complexities to contend with, more responsibilities to discharge.

With taxes the way they are, manager-owners are going to become fewer in number, except for the very smallest of firms. Management responsibilities will therefore be shifted increasingly to the "professional."

Last, the growing complexity of modern business operations, from the point of view of technology, legal restrictions, social responsibilities, trade union encroachment, and global competition, among others, makes it imperative that the highest possible level of competence be devoted to business management.

With the intensely complex enterprise being carried on today, the balance between success and failure is increasingly delicate and the old technique of management is obsolete. Companies are now headed by management teams with competent skills in their various functions and a leader whose particular competence is in management.

SCIENTIFIC APPROACH

The manager-to-be must be trained in the scientific approach—an approach based upon impartial investigation, analysis of all pertinent facts, and orderly solution on the strength of the findings. He must be open-minded to new philosophies and new techniques. The beginning practitioner must have an opportunity to develop a capacity for independent, logical, creative thought. In addition to technical skills acquired, he must also acquire an adequate understanding of those factors governing human existence and interrelationships.

According to Herbert Simon, the work of the manager involves: 1. decisions about the organization structure, and 2. the broader decisions as to the content of the organization's work.

These decisions must be grounded in the organization's technology, and they require an appreciation of the theory of efficiency and a knowledge of those aspects of the social sciences which are relevant to the broader purposes of the organization.

According to Peter Drucker, "the one contribution a manager is uniquely expected to make is to give others vision and ability to perform." Another way to look at this situation is to state that the manager needs to have "process knowledge."

This might be defined as *knowledge about*, rather than knowledge of:

—about what a lathe will do, not how to operate it.
—about what a computer will do, not how to wire it, or how to operate the key punch.

Mr. Pat Haggerty, president of Texas Instruments, Inc., has commented about how his work has taken him away from electrical engineering, per se (his technical education), and into the problems of product strategy, governmental relations, organization planning, and so on—so much so that he is no longer competent to do the work of an electrical engineer because of rapidly advancing technology. He is, however, technically competent to direct their work, to understand it, to plan it, and to judge it.

President McCollum of Continental Oil and Morgan Davis, president of Humble Oil and Refining Company, have made similar statements in regard to their former technical specialities (in both cases geology), now that they are top-level administrators. Also, Mr. Greenewalt of Du Pont, who received his training in chemical engineering, has stated that he has many chemical engineers in his company who are better trained now than he is—that he can no longer keep up with the advances in chemical technology as an engineer, but he dosen't need to in order to do his job properly as general manager.

A very interesting observation has been reported by Chester Barnard in his discussion on executive decision making. Barnard observed that "there are three purposes of mental effort: to ascertain the truth, to determine upon a course of action, to persuade. In any situation, one of the important variables is the need for speed—and there is by no means a correlation between intelligence and the ability to arrive at quick reliable decisions on complicated questions."

Furthermore, he ". . . believes that the junior executive relies chiefly on non-logical processes (except in highly technical fields). With the major executive, logical reasoning processes are progressively necessary but are *disadvantageous if not in subordination to highly developed intuitional processes.*"

What is the significance of this observation? It is that not only the nature of the duties of an executive changes as he progresses upward in responsibilities, but also his reasoning processes. If true, this observation is significant for all persons on their way up the management ladder, especially the engineer inclined to insist on "all the facts" before a decision can be made.

TRAINING AND EDUCATION

How does one acquire such competence? A well-chosen formal education is an important factor—but it must also be stressed that there is no effective substitute for experience in the development of judgment and finesse in relation to managerial problems.

There are some substantial differences in opinion as to the most effective formal education necessary to prepare for management—even as there are differences of opinion as to the most effective means for gaining the requisite experience.

In the opinion of H. M. Hubbard, secretary-treasurer of Harris-Seybold Potter Company, Cleveland, the "industrial engineering courses appear to provide a logical background for the student who definitely aims at the management field."[2] These courses, he believes, "provide the best example of a balanced program between the technical and non-technical phases of business enterprise."

John A. Willard, a partner in Bigelow, Kent, Willard and Company, consulting management engineers, discussed the question of Industrial Engineering and management in considerable detail in a paper presented to the American Society for Engineering Education.[3]

Willard, incidentally, feels that the term "management engineering," or "industrial management engineering," is a more appropriate term for this professional pursuit than Industrial Engineering.

He presented the thesis that management engineering refers to "the ordered application, through the scientific method, of physical law and ethical law to design, planning, building, and adminstration concerned with men, money, materials, markets, methods and government." (You will recognize this as somewhat similar to the definition printed on the back page of our *Journal.*)

He goes on to say that "management engineering is as broad in its application as management itself, but it is different from management in that it treats principally with investigation design, planning, and construction, *rather than with operations.*"

The difference between the two is thus relatively minor, and the opportunity to shift from management engineering to management should be, and is, growing greater as our economy becomes more complex. I would like to get back now to our question about training and education.

According to Willard, there are two general approaches to training in this field:

1. A basic mechanical or similar strictly engineering course, with special studies in economics, administration, accounting, and management superimposed—usually four to five years in duration.
2. The courses provided by schools of business administration, where specialized training in economics, accounting, management, superimposed upon an academic course, without any specific requiremnts for an engineering background—usually four years plus one to two years graduate study.

According to Willard, either of these is satisfactory to prepare recruits for top management or for plant operations. In his opinion, the personal qualities of the individual seem to be considerably more important than the curriculum to which the student is subjected.

For work in the professional field (i.e., as a management consultant, the Education Committee of the Association of Consulting Management Engineers believes that it is desirable for candidates to receive combined

[2] These statements were made in a speech delivered at the Annual Meeting for the Promotion of Engineering Education, June 20, 1939.

[3] This presentation was reproduced in the ACME Bulletin #35.

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engineering and business administration training. The Committee proposes a six-year course of study—after which the program at The University of Texas labeled "The Engineering Route to the BBA Degree" is modeled. Essentially, the same approach was used some forty years ago when Professor Erwin Shell developed his famous Course 15 at Massachusetts Institute of Technology; Northwestern University, Carnegie Tech, Stanford, and Wharton School are others following this approach.

There is also a large number of schools which follow different approaches to this problem of training management engineers—and recruits for top management.

SUMMARY

We are not yet ready to state with any degree of assurance which way is best, if, in fact, any one type of education is best. Certainly, the evidence is still inconclusive.

Let me emphasize, that management and management engineering are different. Each, however, is vital to the efficient and effective operation of an enterprise. Management needs the engineer, and the engineer needs management. Neither can do his best without the help of the other. While each one is different, the mobility between the two pursuits is fairly high, and naturally so.

One of the founders of the science of management, the great French steelmaker, Henri Fayol, pointed out over sixty years ago, that the engineer's job was eighty-five percent technical, but as the same person moved into the practice of management, his need for managerial competence became such that he needed to add to his technical skills greatly increased managerial skills in planning, organizing, directing, and controlling, until these added skills comprised eighty-five percent of his knowledge (4). Fayol concluded that ". . . the most important ability on the part of the manager is managerial ability and the higher the level of authority the more dominant this ability."

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An Experimental Investigation of Priority Dispatching[1]

by RICHARD W. CONWAY, BRUCE M. JOHNSON *and* WILLIAM L. MAXWELL

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THIS is a report on the first phase of an investigation into certain aspects of shop scheduling. The investigation is concerned entirely with the dispatching function of scheduling—the detailed determination of sequence of work for individual machines—and further is concerned only with the simplest type of procedures for accomplishing this—rules that operate in real-time, *making decisions as they are required,* and which do not attempt to lay out a plan for many jobs and many machines well into the future. The rules of interest are those that simply resolve the conflict that arises whenever two or more jobs are waiting for the services of a single machine and the decision must be made as to which to process first. We call all such rules *priority rules*—perhaps a more general meaning than is often associated with this term. Our basic tenet is that the job with the maximum priority of those waiting for a particular machine will be processed first. Our investigation concerns the many different ways in which a priority can be assigned to these jobs.

It is not our intent at this time to argue the significance of this phase of the scheduling function, the efficiency of this type of rule as opposed to rules that develop a complete plan over an interval of time, or the practicality of certain of the rules. For justification it is sufficient that rules of this type are in fact in widespread use and relatively little is known about their properties. Our objective is to compare the properties of some of these rules in an attempt to discover whether there exist consequential differences between them.

We are interested in how diffrent rules affect the following measures of performance in the shop:

1. The distribution of times to complete a job—time from introduction to the shop to the completion of processing on the last operation.
2. The distribution of lateness of jobs—the length of time between the actual completion of a job and the desired completion.
3. The amount of work-in-process inventory in the shop.
4. The utilization of shop facilities—the complement of idle time.

We treat each of these measures separately (although their values are often related) and do not, by means of attaching a cost coefficient to each, obtain a single comprehensive measure of goodness.

This approach considers a shop to be basically a network of queues. Since the topic of investigation is the queue discipline much of the results of queueing theory are inapplicable and to date analytical treatment of the problem has not proved fruitful. However, the queueing theory has been most helpful in planning experiments and in analyzing results. Of particular interest is the work of Jackson (6) and Nelson (8).

There has been previous experimental work by computer simulation on the topic of priority dispatching at U.C.L.A., (4) (5) (7) (10) (11) (12), The General Electric Company (9), and The International Business Machines Corporation (1). The present work involves considerable differences in the rules tested, the conditions under which the tests were performed, and the conclusions drawn, but where comparable there does not appear to be any basic conflict in either data or conclusions.

The experimental investigation was conducted through the use of the Cornell Research Simulator (2), a program which simulates the operation of a network of queues on a basic punch-card IBM 650 computer. Constructed for this purpose, this program readily accommodated the various different decision rules to be tested. Although the Cornell Computing Center was most generous with computer time, and the 650 performed gallantly, the limitations both in storage space and operating speed of that medium-scale computer were a dominant factor in the design of the experiment that was performed. It was apparent from the outset that there were so many possible rules to be considered and so many other parameters (of dimensions, distributions, conditions) to be varied that a "complete" experiment would be impossible. It was decided to test a considerable number of rules, under a limited set of conditions using test runs of relatively short duration. From the results of this work a smaller number of rules could be selected for more intensive study.

[1] This work was supported by the Office of Naval Research under Task NR 047-023. A preliminary version of this paper titled "Simulation Research in Shop Scheduling" was presented to the National Convention of the American Institute of Industrial Engineers in Atlanta, May, 1959. The authors are indebted to Dr. Ivan Rezucha of the IBM Corporation for his many helpful suggestions.

PRIORITY RULES

The following priority rules were tested. They are numbered here and identified by that number in the description of results.

1. Priority value assigned at *random*.

2. Priority given in arrival order (FIFO). The first arrival in a queue receives the highest priority; a strictly decreasing sequence of priority values is assigned to jobs as they arrive in a particular queue.

3. Priority value is inversely related to the *due-date* of the job. The job with the earliest due-date has the highest priority.

4. Priority is inversely related to the remaining "*slack-time*." Maximum priority is given to the job for which the time remaining to due-date less the remaining processing time is a minimum.

5. Priority is inversely related to the processing time on the coming operation. Maximum priority is given to the job with the *shortest operation* on the machine in question.

6. Priority is directly related to processing time on the coming operation. Maximum priority is given to the job with the *longest operation* on the machine in question.

7. Priority is inversely related to the number of remaining operations. Maximum priority is given to the job with the *fewest remaining operations*.

8. Priority is directly related to the number of remaining operations. Maximum priority is given to the job with the *most remaining operations*.

9. Priority is inversely related to the total remaining processing time. Maximum priority is given to the job for which the *sum* of the *processing times* for all *remaining* operations is a *minimum*.

10. Priority is directly related to the total remaining processing time. Maximum priority is given to the job for which the *sum* of the *processing time* for all *remaining* operations is a *maximum*.

11. Priority depends upon the (dollar) value of the job. Jobs are divided into two classes—a high-value class and a low-value class. All high-value jobs are assigned greater priorities than all low-value jobs. Within the class, priority is assigned in arrival order (Rule 2). There is actually a family of rules of this type which can be parameterized by P, the proportion of jobs assigned to the low-value class.

12. Priority is directly related to the (dollar) value of the job. The priority is taken to be equal to the value of the job.

13. Priority is related to the subsequent move. Maximum priority is given to that job which on leaving this machine will go on to the next machine which has the shortest (in the sense of least processing time) critical queue. If no queue is critical the selection is in arrival order—Rule 2. A queue is considered critical when it has less than a specified number of time units of processing time waiting. There is actually a family of rules of this type which can be parameterized by Q, the value below which a queue becomes critical.

TEST CONDITIONS

The tests were performed upon a shop that consisted of five machines, all different. This admittedly small shop was selected for reasons of economy of computing time. However, we find some small reassurance in the work of Baker and Dzielinski (1) who tested shops of from nine to thirty machines and found that the size of the shop was "not significant." We appreciate the hazard of extrapolating this result, and are currently further investigating the effect of shop size.

The jobs were generated synthetically by a program that operated from a table that gave the probability of moving from each machine to every other machine, and from the distributions of operation times. The table of probabilities was constructed so that a. the expected number of operations on each machine was equal and b. there is a general pattern of flow through the shop rather than completely random movement. The operation time distributions were skewed to the right (a Poisson distribution with the probability ordinarily associated with zero added to the probability of a time of one unit). There was no consideration of the effect of imperfect *a priori* knowledge of operation times; the actual operation times were assumed to be known in advance. The Job Generation Program produced a deck of cards, each card representing an individual job. This necessarily truncated the distribution of the number of operations per job to a maximum of seven. The average number of operations per job was approximately four. The order in which the jobs were "released to the shop" was entirely determined by the card order in the read-feed; the rate at which they were released was internally controlled by the Simulator.

The jobs were assigned a (dollar) value from a distribution that was highly skewed to the right (Log Normal). The assignment was random—completely uncorrelated with any of the processing characteristics of the job—and the value did not change as the job proceeded through processing.

The jobs were assigned a Total Allowable Processing Time (Due-Date minus Release-Time) from a Normal distribution with the mean selected so that the average lateness would be approximately zero, and the standard deviation was approximately 5% of the average Total Allowable Processing Time.

It seemed not unreasonable to believe that the level of load upon the shop could have a serious influence on the comparative performance of priority rules. A rule that was superior under conditions of heavy load might not be advantageous when the shop was lightly loaded. To investigate this possibility the rules were compared at three different levels of shop load, designated as Heavy, Medium and Light.

METHOD OF OPERATION

The intent was to study the job shop as an equilibrium or steady-state process. The Simulator would run continuously with no attempt to divide its time scale into shifts, days or weeks, or to periodically release batches of jobs. It was necessary to run the system for a considerable period of time before the transients induced by the artificiality of starting could decay and stability be achieved (3). Performance sampling did not begin until a near-equilibrium was achieved. Two techniques were employed to accelerate the attainment of this condition. First, although the straightforward method of operation would probably be to fix the release rate of jobs (which might include a stochastic mechanism) and to measure the resulting number of jobs in the shop under different priority disciplines, preliminary tests indicated that sta-

bility was achieved much more rapidly by fixing the number of jobs in the shop and measuring the rate of release under different priority disciplines. The program was simply set to read in a job each time one was completed. Second, the run-in period was greatly reduced by preloading the shop with a set of "half-finished" jobs that was very similar to the steady-rate condition of the shop. This condition could not be predicted exactly, of course, or there would have been no purpose in the test, but the pre-load was certainly much closer to the desired condition than was an empty shop.

Following the initial run-in period was a sample period during which performance measurements would be obtained. The exact determination of the sampling process presented many problems. Certain of the measures of interest—job completion time and lateness—could be obtained by sampling jobs and constructing a sample distribution. There are a number of different ways of obtaining the sample. The easiest is certainly to select n consecutive jobs from the output of the process. However, this requires considerable confidence that steady-state conditions have actually been achieved—in particular, that jobs with very long completion times have a chance of appearing in that sample that is commensurate with their proportion in the true population. Alternatively, one could designate n consecutive input jobs as the sample jobs and obtain the sample distribution from these jobs, whenever they were discharged from the system. The latter procedure was selected, as being relatively less sensitive to the achievement of steady-state conditions.

Under certain priority rules (FIFO—Rule 2; Lateness —Rule 3; Slack-time—Rule 4) this appears to be entirely satisfactory. However, under other rules (Random—Rule 1; Shortest Operation—Rule 5 and others) there was a great deal of difficulty in obtaining data on n consecutive input jobs; although a large proportion of the jobs would run through the system very quickly, a few of the jobs would remain in the system for a long period of time and waiting for the nth job to emerge became intolerably consumptive of machine time.

In order to conserve machine time, and still avoid difficulties of comparison if some of the samples were not run out completely, it was naively decided to uniformly truncate all tests at 85% run out. A sample of 100 consecutive identifiable jobs was read in; performance statistics were based on the first 85 of these jobs to be completed.

It was soon apparent that this procedure was far from satisfactory and gave a considerable advantage to certain types of priority rules. In an attempt to overcome this difficulty and still not lengthen the test runs a second mode of operation was instituted; when the 85th job was completed the remaining fifteen jobs were "forced out" as if they had been completed simultaneously with the 85th job and statistics were based on the entire 100 jobs.

When this still left much to be desired, and when the end of the school year reduced the load on the Computing Center we finally, resignedly, repeated many of the tests, running out the full 100 jobs. Data from all three modes of operation (labeled Truncated 85, 85 Force Out, and 100 Run Out) are presented. The truncated data are presented in addition to the full run out data for two reasons: first, as an illustration of a serious procedural problem in simulation, which may be of some interest to others planning similar work; second, because it is just possible that rules that have good properties for a large proportion of jobs are actually of greater practical significance than those which are superior for full run out. It is possible that the upper tail of the distribution might be truncated in practice by the use of overtime, second shift operation, sub-contracting, or just supervisory pressure.

To give an idea of the amount of computer time involved, a test involving complete run out of the 100 sample jobs required approximately 10 minutes for certain rules (FIFO—Rule 2) and as much as an hour for others (Shortest Operation—Rule 5).

The dollar-days of queue time was similarly computed from the sample jobs and is subject to the same sort of difficulty. The final measure of performance was facility utilization. A complete record, from the beginning of the sample jobs, was kept and this measure presented no problem.

In summary, the order of leading job cards was the following:

Deck 1. Pre-load consisting of "half-finished" jobs, number depending upon the shop load.

Deck 2. Initial jobs to allow shop to "settle-down," number depending upon the shop load.

Deck 3. 100 identifiable sample jobs.

Deck 4. Run-out jobs to keep the shop operating in steady-state condition until the sample jobs are run out.

Decks 2, 3 and 4 were all generated in the same manner by the Job Generation Program. Deck 3 differs only in the presence of an identification digit on the sample jobs.

TABLE 1

Job Lateness

Light Load

Truncated 85

Rule	Mean Lateness $\bar{L}$	Std. Dev. $\bar{a}_L$	% of Jobs Late
1	−10.1	22.8	26.3
2	− 9.3	16.1	26.7
3	− 9.2	14.0	18.8
4	− 9.9	13.5	19.2
5	−13.3	29.4	16.9
6	− 8.6	29.8	28.6
7	−11.7	28.4	17.3
8	−11.9	29.4	27.1
9	−12.5	29.3	14.5
10	−10.4	31.1	24.7
11 ($P=0.3$)	−10.5	29.2	23.9
12	−13.3	30.1	20.0
13 ($Q=5$)			
($Q=10$)			
($Q=99$)			

TABLE 2

Job Lateness

Medium Load

Rule	Truncated 85		85 Force Out			100 Run Out	
	$\bar{L}$	$\bar{s}_L$	$\bar{L}$	$\bar{s}_L$	%	$\bar{L}$	$\bar{s}_L$
1	−19.3	54.6	−19.0	55.4	28.3	−11.3	61.8
2	−11.8	38.9	−17.5	41.2	34.3	−11.8	37.1
3	−14.0	30.9	−18.6	32.0	24.7	−11.5	27.3
4	−12.7	31.2	−16.1	31.6	23.3	−12.4	26.5
5	−50.5	75.1	−36.0	78.9	17.0	+ 4.0	227.6
6	−31.0	77.7	−24.3	80.4	23.3		
7	−46.8	60.9	−36.0	62.7	14.0		
8	−48.0	80.5	−32.4	88.5	22.7		
9	−46.3	66.1	−36.9	66.6	13.7		
10	−38.9	83.7	−27.2	83.9	29.3		
11 (P=0.3)	−36.2	85.5	−24.1	87.1	27.3	− 0.8	126.7
12	−54.9	83.9	−35.4	91.9	20.7	+ 4.8	207.4
13 (Q= 5)	−17.8	45.2				−14.2	47.2
(Q=10)	−20.9	43.1				−15.5	54.9
(Q=99)	−30.6	47.2				−15.9	54.2

Three decks were generated for each level of load. Each deck was run under each of the priority rules. The data given are in every case obtained from three independent samples of 100 jobs each. Testing each rule on the same set of jobs, rather than drawing an independent sample of jobs for each test, eliminated one sizeable source of variability in the experiment (3).

RESULTS[2]

A summary of the distributions of job lateness for light, medium and heavy loads is given in Tables 1, 2 and 3. In each case the data are obtained from three samples of 100 jobs each. $\bar{L}$ is the overall mean lateness of the three samples. $\bar{s}_L$ is the mean of the three sample standard deviations. % Late is the mean of the percentage of mean jobs from each of the three samples. The mode of operation is indicated in the tables. "Lateness" as used here is completion date minus due-date, where both positive and negative values are considered. In numerous cases the mean lateness is negative—indicating that on the average the jobs were completed before their due-dates.

The due-dates were assigned so that the mean lateness would be approximately zero, but the comparison between rules in a given table is significant rather than the absolute values. No direct comparison between the tables for different loads should be made since the jobs while having the same operations, were given different due-dates for the different loads. In order to evaluate the magnitudes of the latenesses the average total processing times (completion time minus release date) are of interest:

Load	*Approximate Average Total Processing Time*
Light	60 Time Units
Medium	120 Time Units
Heavy	200 Time Units

The percentage utilization of capacity under the different rules is given in Table 4. The figure given is the mean of the utilizations obtained in the three independent runs.

TABLE 3

Job Lateness

Heavy Load

Rule	Truncated 85		85 Force Out			100 Run Out	
	$\bar{L}$	$\bar{s}_L$	$\bar{L}$	$\bar{s}_L$	%	$\bar{L}$	$\bar{s}_L$
1	−38.5	92.7	−30.5	92.4	31.0	− 9.5	122.2
2	−15.2	59.1	−23.5	63.4	33.7	−10.1	61.7
3	−17.8	38.9	−21.6	45.6	27.0	−12.9	38.6
4	−15.7	39.8	−17.1	44.5	26.3	−16.9	36.3
5	−112.7	147.2	−75.5	140.8	17.3	+63.9	598.9
6	−79.2	137.2	−57.0	137.1	22.3		
7	−92.1	118.9	−57.4	106.6	16.3		
8	−100.1	152.5	−58.4	169.8	26.3		
9	−97.2	129.1	−58.1	132.9	21.0		
10	−85.3	152.2	−45.0	159.1	28.0		
11 (P=0.3)	−64.9	178.1	− 6.6	211.8	32.0	+28.7	281.9
12	−104.1	165.1	−40.1	200.8	25.7	+87.2	558.1
13 (Q= 5)							
(Q=10)							
(Q=99)							

TABLE 4

Utilization

Rule	Light Load	Medium Load	Heavy Load
1	80.2%	93.0%	93.7%
2	80.3	93.0	94.2
3	80.1	93.9	94.7
4	80.0	94.2	94.1
5	83.5	97.3	99.2
6	75.3	89.2	91.5
7	79.6	94.2	95.1
8	79.0	93.1	95.5
9	80.4	94.4	95.2
10	77.4	89.1	92.9
11 (P=0.3)	78.8	93.0	94.1
12	79.3	92.2	94.0
13 (Q= 5)		94.6	
(Q=10)		95.6	
(Q=99)		95.1	

With the exception of Rules 11 and 12 these rules do not consider the dollar value of the job in any way. Since the value bears no relationship to any other characteristic of the job the dollar-days of queue inventory is directly proportional to completion time and lateness. These data are not shown.

Rules 11 and 12 do consider the value of the job and are designed to reduce the dollar-days of queue inventory by accelerating the progress of high value jobs through the shop. By testing Rule 11 with different values of P (the proportion of jobs in the low value class) one can search for the "best" two-class rule—the one which makes the mean dollar-days of queue inventory a minimum. These data are given in Table 5 and plotted in Figure 1. It would seem reasonable to expect that the best three-class rule would be better than the best two-class rule; the best four-class better than the best three-class, etc. However, as the number of classes increases it becomes increasingly difficult to discover the best multi-class rule. However, it is very easy to give a limiting rule—a rule that considers each different value of a class by itself. Such a rule should be the best of all multi-class rules. This is Rule 12; appropriate data are given in Table 5 and Figure 1.

[2] The authors are indebted to A. Ginsberg, R. Larsen, C. Nugent and H. Von Falkenhausen who assisted in the execution of these experiments.

TABLE 5

Average Dollar-Days of Queue Inventory

Rule	Light Load	Medium Load			Heavy Load		
	Trunc. 85	Trunc. 85	85 Force Out	100 Run Out	Trunc. 85	85 Force Out	100 Run Out
11 ($P=0$)	350	1005	1040	1123	1769	1926	2154
($P=1$) Equivalent to Rule No. 2							
($P=.2$)	277	611		780	1195		
($P=.3$)	263	524	564	683	769	1106	1278
($P=.4$)	253	502		671	768		
($P=.6$)	265	573		689	899		
12	216	361	409	543	566	746	1125

DISCUSSION

Discussion should probably begin by considering what properties of priority rules are of interest and what comparisons should be drawn. It is obvious that by favoring a particular job and giving it preference over all other jobs it can be forced through the shop in less time than it would "normally" have taken. It is equally obvious that this acceleration takes place at the expense of other jobs. But the overall result, considering all jobs, of a procedure that favors jobs to different degrees is not at all obvious.

One question of general interest, then, is the form and particularly the range of reference of the distribution of completion times (or latenesses). It would seem likely that there are rules that could decrease the variance of the distribution (from "normal" value) by favoring jobs that either because of their characteristics or just by chance are becoming late. It is equally likely that there are rules which could increase the variance of the distribution. The existence of rules that would exhibit these properties would hardly seem to require proof. But quantitative information—the magnitude of the effects, and the comparison of specific alternatives is quite another matter.

A fundamental question about priority rules is the following: Granted that different priority rules can alter the form and variance of the completion time distribution, can the choice of priority rule change the *mean* of the distribution? Can one rule be better than another in the sense that under equivalent conditions it has a shorter average completion time? The following analysis is very useful in the consideration of the experimental results.

THE EQUATION OF STEADY-STATE FLOW FOR THE JOB SHOP PROCESS

Assume that a job shop process is conservative and operating in equilibrium—the average arrival rate is not time-dependent and is equal to the average departure rate. The following is a steady-state flow equation for the process:

$$E(X_i) = E(N_i) \cdot E(Y_i) \qquad \text{Eq.1.}$$

where

X_i is the completion time (total time to process) for the ith job.

Y_i is the arrival interval—the time between the arrival of the ith and the $i+1$ job.

N_t is the number of jobs in the shop at time t.

$E(\ )$ represents the expected value, or average, of the variable. The relationship is easily proved. It holds for all priority rules, and under all conditions of load and capacity, and does not depend upon characteristics of the jobs—routing, operation time distributions, or accuracy of estimates.

A similar expression can be obtained for the mean lateness. By definition:

$$L_i = X_i - A_i$$
$$E(L_i) = E(X_i) - E(A_i) \qquad \text{Eq.2.}$$

where

L_i is the lateness of the ith job

A_i is the allowed time in the shop for the ith job.

Combining Eq. 1. and Eq. 2.:

$$E(L_i) = E(N_i) \cdot E(Y_i) - E(A_i) \qquad \text{Eq.3.}$$

$E(A_i)$ is a property of the Job Generation Program and

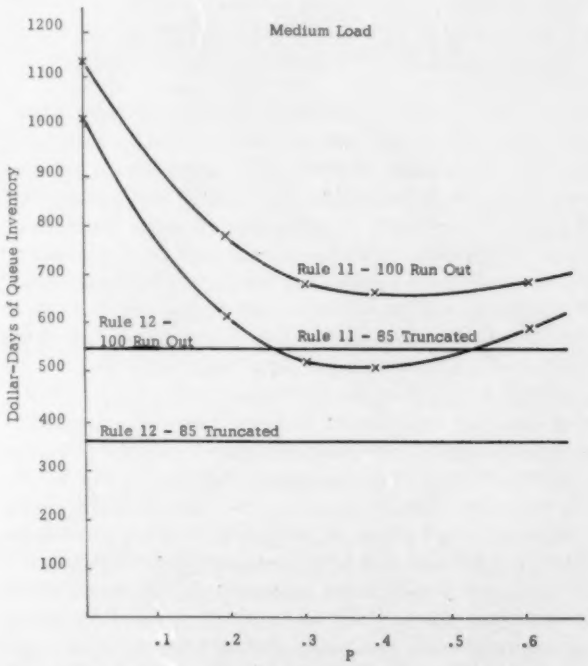

FIG. 1. Dollar-Days of Queue Inventory versus Proportion of Jobs in Low-Value Class.

is the same for all rules. The following conclusions are possible:

If the mean arrival interval is held constant, the mean completion time (or lateness) is directly proportional to the mean number of jobs in the shop *for all priority rules*. If two priority rules are to be compared by tests in which the mean arrival intervals are equal for the two rules, rule A will have a shorter mean completion time (or lateness) than rule B if, and only if, it causes there to be a smaller mean number of jobs in the shop.

If the mean number of jobs in the shop is held constant, the mean completion time (or lateness) is directly proportional to the mean arrival interval *for all priority rules*. If two priority rules are to be compared by tests in which the mean number of jobs in the shop are equal (in particular, where $N_t = N$ for all t) for the two rules, rule A will have a shorter mean completion time (or lateness) than rule B, if and only if it has a shorter mean arrival interval.

Let $E_r(Y_i)$ be the mean arrival interval (time units between job arrivals) for rule r, $E(W_i)$ be the mean number of time units of actual processing time per job, C be the capacity of the shop (time units of work per time unit), and $E_r(U)$ be the mean proportion of capacity utilized under rule r. Then:

$$E_r(Y_i) = \frac{E(W_i)}{C \cdot E_r(U)}$$

Substituting for $E(Y)$ and setting $E(N) = N$ in Eq. 1. and Eq. 3.

$$E_r(X_i) = \frac{N \cdot E(W_i)}{C \cdot E_r(U)} \qquad \text{Eq.4.}$$

$$E_r(L_i) = \frac{N \cdot E(W_i)}{C \cdot E_r(U)} - E(A_i) \qquad \text{Eq.5.}$$

$E(W_i)$, N, C, and $E(A_i)$ are the same for all rules. Thus, the mean completion time and the mean lateness are inversely proportional to the facility utilization.

Consider Rule 1, the Random Rule, as a standard rule. $E_{RN}(U)$, $E_{RN}(X)$ and $E_{RN}(L)$ are the mean utilization, mean completion time, and mean lateness respectively, for this rule. Now consider the set, R, of all priority rules which have mean utilizations equal to $E_{RN}(U)$. It follows that members of this set also have mean completion time equal to $E_{RN}(X)$, and mean lateness equal to $E_{RN}(L)$. It does not follow that all members of R are equivalent; they can vary with respect to the variance of completion time and lateness, and with respect to various different weighted averages (for example, weighting by job value) of completion time.

Now consider which of the priority rules previously listed can be excluded from membership in R. Grounds for exclusion would be either greater or less ability than the random rule to *avoid idle machine time*. Rule 13 is immediately and obviously excluded. Since this rule selects a job for processing which will then go to a machine where the danger of idle time is imminent, it would be expected to achieve greater utilization than the random rule.

The membership of the other rules is less obvious. It is well known that in a single channel queue a discipline that favors jobs with short processing times tends to reduce the average queue length. Thinking of a test in which the average arrival interval was fixed, one might extend this argument to a network of queues to conclude that the shortest operation rule (Rule 5) would have a lower mean number of jobs in the shop than the Random Rule, and hence, a smaller mean completion time. A not unreasonable argument would then conclude that where the mean number of jobs was fixed the shortest operation rule would yield a shorter mean arrival interval, and hence a greater utilization, than the random rule. If this is true and Rule 5 is not a member of R, then certainly Rule 6 is not a member of R. Rule 6 is the antithesis of Rule 5; if Rule 5 achieves a greater utilization than the Random Rule, then Rule 6 should achieve a lesser utilization.

In general, any rule which considers the operation time can be suspected of having some effect on queue length, and on utilization. For example, Rule 9 favors the job with the smallest total remaining processing time. Priority under this rule should be slightly correlated with priority under Rule 5; in the case of a job waiting for its last operation, priority under the two rules would be identical. Rule 10 is similarly related to Rule 6. Rule 4 considers processing time in computing the slack-time. In favoring a job with smallest slack-time it would seem to be related to Rule 10, however remotely.

The other rules base priority determination upon characteristics that are entirely independent of processing time—order of arrival, number of operations remaining, value of the job—and should not affect the utilization.

In summary, we approach the experimental results with the following hypothesis:

1. Priority Rules 2, 3, 7, 8, 11, and 12 are members of set R, the set of all rules which have the same steady-state utilization as the Random Rule (Rule 1).
2. Priority Rules 4, 5, 6, 9, 10, and 13 are not members of R.
   a. Rules 5 and 13 are members of $R+$, the set of all rules having utilization greater than that of the Random Rule.
   b. Rule 6 is a member of $R-$, the set of all rules having utilization less than that of the Random Rule.
   c. Rule 9 is a member of $R+$, with $E_9(U) < E_5(U)$—the utilization for Rule 9 less than the utilization for Rule 5.
   d. Rule 10 is a member of $R-$, with $E_{10}(U) > E_6(U)$.
   e. Rule 4 is a member of $R-$.

Note that equations Eq. 1. to Eq. 5. are not hypotheses, subject to verification or rejection, but are known statements of fact. Set R is defined so that Rule 1 is a member. The only question is the membership of Rules 2 to 13.

DISCUSSION OF EXPERIMENTAL RESULTS

Membership in R can be judged either by utilization, or by mean lateness, or both. The utilization data (Table 4) are more complete, more stable, and apparently little

affected by the problems of truncation and sample run-out. The differences in these data are not large, but it should be noted that an increase in utilization from 93 to 95% represents approximately a 30% decrease in idle time.

Utilization data for Rule 13 are given for medium load only. For all three values of Q tested the utilization is greater than that of the Random Rule, giving no reason to doubt that Rule 13 is in $R+$ rather than R.

Consider the first 12 rules. The maximum utilization of any rule for each value of load is achieved by Rule 5. In each case it is considerably greater than for any other rule, lending strong support to the hypothesis that Rule 5 is in $R+$. There would seem to be some support for the hypothesis that Rule 9 is also in $R+$; it achieves the second greatest utilization for the light and medium load, the third greatest for the heavy load case. However, in each case the differences between Rule 9 and the other rules are not great and one would not even mention the "higher" value for Rule 9 if it were not for the consistency with which it appears under different values of load.

At the opposite end of the scale the utilization for Rule 6 is rather a clear cut minimum for both light and heavy load; and second smallest (but still considerably less than the Random Rule) for medium load. This tends to support the hypothesis that Rule 6 is in $R-$. Moreover, considering the nature of Rules 5 and 6, the high values of utilization observed for Rule 5 and the low values for Rule 6, taken together, are somewhat mutually reinforcing.

The utilization for Rule 10 is the minimum value for medium load, and the second smallest value for light and heavy load. This supports the hypothesis that Rule 10 is in $R-$, and lends some support to the conclusion with regard to Rule 9.

There do not appear to be any consistent differences between any of the other rules—these data give no reason to doubt that Rules 2, 3, 4, 7, 8, 11 and 12 are members of R.

It is also of interest to observe how utilization varies with the number of jobs in the shop for a given rule. These data are plotted for Rules 1, 5, and 6 in Figure 2. It is apparent that for any given rule utilization increases with the number of jobs, at first quite rapidly, but finally very slowly. Knowledge of this relationship, obtained either analytically or empirically, would be most useful in determining optimum operating conditions for a shop —the load level for which the sum of the cost of idle facilities and the cost of work-in-process inventory is a minimum.

Now consider the mean lateness for the full 100 job run-out under the various rules (Tables 2 and 3). Using the values of utilization from Table 4, Eq. 5., known properties of the Job Generation Program, and the mean lateness for the Random Rule, one can estimate what the mean lateness should be for the other rules. These estimates are given in Table 6.

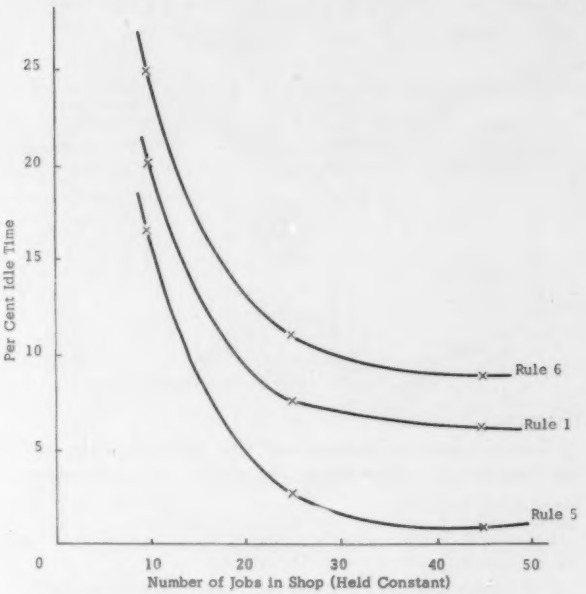

FIG. 2. Idle Time versus Number of Jobs in Shop for 3 Priority Rules.

One would not expect these values to coincide exactly, since the estimating equation is based on expected values and both the utilization values used in the equation and the mean lateness to which it is being compared are obtained from rather small samples. Moreover the utilization and mean lateness are not obtained from exactly the same jobs—utilization is measured from the beginning of the sample jobs to the end of the run; mean lateness concerns only the sample jobs.

The mean latenesses for Rules 2, 3, 4, and 13 are not unreasonable and do not contradict any of the previous remarks about classes of rules. For Rules 5, 11 and 12 the mean latenesses are substantially greater than would be expected, for both medium and heavy loads. This provides clear evidence that steady-state conditions were not in fact attained—at least not for these rules. It is clear that both the nature of steady-state conditions and the rapidity with which these conditions can be attained vary widely with priority rule.

A comparison of the data for runs truncated at 85 jobs, 85 force out and full 100 job run out clearly indicates the tremendous impact upon results of the method of measurement. The most egregious example is for medium load, where Rule 12 has the minimum mean lateness of all rules for the truncated 85 data, and the maximum mean lateness of all rules for the 100 run out data. The effect of truncation is far from uniform upon all rules. Rules under which the lateness distribution has large variance and is skewed to the right have the mean greatly reduced by discounting the upper tail of the distribution (Rules 5, 11, 12). Low variance rules are very slightly affected by

TABLE 6

Mean Lateness

100 Run Out

Rule	Medium Load		Heavy Load	
	Estimate	Observed (Table 2)	Estimate	Observed (Table 3)
1	—	−11.3	—	− 9.5
2	−11.3	−11.8	−10.5	−10.1
3	−12.3	−11.5	−11.5	−12.9
4	−12.7	−12.4	−10.3	−16.9
5	−16.1	+ 4.0	−20.2	+63.9
11 ($P=0.3$)	−11.3	− 0.8	−10.3	+28.7
12	−10.4	+ 4.8	−10.1	+87.2
13 ($Q=5$)	−13.1	−14.2		
($Q=10$)	−14.2	−15.5		
($Q=99$)	−13.7	−15.9		

truncation (Rules 2, 3, 4).

Considering the variance of the lateness distribution one can describe four types of priority rules, in order of increasing variance:

1. Lateness Rules—rules that assign priority according to some increasing function of lateness (Rules 3, 4).
2. Arrival Order Rules—rules that assign priority in order in which jobs arrive (Rule 2).
3. Random Rule—priority assigned at random (Rule 1).
4. Rules that assign priority according to some property of the job itself (Rules 5, 6, 7, 8, 9, 10, 11, 12, 13).

Rules of type 4 are intended to accomplish some other objective—minimize inventory, maximize utilization, or others. To do so they select from available jobs according to properties related to the objective, accelerating some jobs and retarding others, thereby increasing the variance of the lateness distribution.

The variance of the lateness distribution cannot be immediately identified with the predictability of the lateness of an individual job. This might be appropriate if the mean lateness were the best estimate of the individual lateness, but better estimators are possible. For example, the value priority rule (Rule 12) has very high variance, but it is possible that there is a very strong correlation between lateness and value, so that knowing the value of a specific job one could give a good estimate of what its lateness would be.

DISCUSSION OF QUEUE INVENTORY

A consideration of the dollar-days of inventory resulting under various decision rules is interesting in itself, but more important, it is representative of a general class of measures of performance—a weighted distribution of completion times. In this case the job completion times are weighted by value; they could be weighted by any other job characteristic—some index of importance, urgency, volume, etc. The question is the design of a priority rule to minimize the sum, or mean, of the weighted statistic.

Say that we have N jobs. Let V_i, $i = 1, \ldots, N$ represent the value of these jobs. Let X_{ri}, $i = 1, \ldots, N$ represent the completion time for the ith job under decision rule r. Our objective is to specify r so as to minimize

$$\sum_1^N V_i X_{ri},$$

or equivalently, minimize the mean:

$$\sum_1^N V_i X_{ri}/N.$$

Suppose that the sequence of completion times was the same for each rule r; that a rule simply consisted of the assignment of completion times to individual jobs. In this case it is well known that an optimum rule would assign the maximum completion time to the job with minimum value, the second largest completion time to the job with the second smallest value, etc. However, the decision rule actually determines the magnitude of the completion time as well as assigns them to jobs. Thus a rule that makes the max-min pairing described *could* be non-optimal simply because another rule results in smaller values for X_i. Moreover, even restricting consideration to rules of set R, one cannot state that max-min pairing is a sufficient condition for an optimal rule. At present we can only conclude that a "good" rule will have the following characteristics:

1. It will approach a max-min pairing of completion times and weights.
2. It will have a low mean completion time.
3. It will have a large variance of completion times.

The queue inventory measure used here is the following:

$$I = \sum_1^N \frac{V_i Q_i}{N} = \sum_1^N \frac{V_i X_i}{N} - \sum_1^N \frac{V_i M_i}{N}$$

where V_i is the value of the ith job, Q_i is the total time spent in queue for the ith job and M_i is the total machine time for the ith job. This represents a measure of the inventory that is theoretically avoidable—it does not include an inventory charge while the job is actually being processed—and differs from the weighted completion only by a constant term. Table 5 and Figure 1 plot this measure against the proportion of jobs in the low value class for a two-class priority rule (Rule 11). The end points—$P = 0$ and $P = 1$—are equivalent to the FIFO rule (Rule 2). That the curve would be regular and convex could be anticipated. But the magnitude of the convexity and the value of P associated with the minimum of I would not be anticipated. One would expect that the "best" three-class rule would be better than the "best" two-class rule, the best four-class better than three, etc. The limit of this argument would be a rule having infinitely many classes—where each value is considered a class in itself. The results for such a rule (Rule 12) are also shown on Figure 1 and in Table 5. One can conclude that a considerable reduction in the measure I can be

achieved by the use of a "good" two-class rule. For both medium and heavy load the minimum value of I is approximately 60% of the value associated with the FIFO rule (Rule 11, $P = 0$). Thus, a greater reduction is achieved by the use of a good two-class rule than by going further to a greater number of classes—the value for Rule 12 is only 50% of the FIFO value. One should note that the price paid for this reduction in inventory is a tremendous increase in the variance of the lateness distribution.

It is of interest to note that the minimum of the curve in Figure 1 is quite flat—the rule is not extremely sensitive to the exact value of P used—and that the minimum occurs at a surprisingly low value of P.

To what extent these characteristics and observations depend upon the particular distribution of job values that was used, we do not yet know.

CONCLUSIONS

Priority rules can differ with respect to the mean completion time or mean lateness of all jobs as well as the values for individual jobs. A priority rule can do more than accelerate one or more jobs at the expense of others—it can accelerate the average of all jobs.

Priority rules differ very greatly with respect to the variance of the distribution of job lateness. At one extreme are the variance-minimizing "lateness" rules that favor the job with the greatest current lateness. At the other extreme are rules that select jobs according to some characteristic that does not depend upon when this job arrived or when it is supposed to be completed. Rules of the latter type can have a variance 100 times as great as rules of the former type.

Simple priority rules can do an effective job of reducing a weighted average completion time, as compared to the selection of jobs at random. Where the completion time was weighted by the value of the job, a rule that gave preference to jobs in order of value demonstrated a reduction of 50%. A rule that simply segregated jobs into two classes, giving preference to members of one class, proved almost as effective. Determination of the point of division between the classes is important, but in the neighborhood of the optimum performance is not highly sensitive to the value used.

DIRECTION FOR FURTHER INVESTIGATION

One of the initial objectives of this work was a desire to find out if serious investigations by means of digital simulation could be pursued on a medium-scale (magnetic drum) digital computer. We believe that with patience and ingenuity, and considerable generosity with machine time, this is possible. That being established we will gratefully take advantage of the acquisition by the Cornell Computing Center of a machine of considerably greater power to continue our work. Preliminary runs have indicated a time advantage of a factor of about 25 which will make possible experimental designs and sample sizes which just were not practical on the smaller machine.

The following projects are presently under way:

1. Continued investigation of Rules 1, 2, 5, 11, 12, 13 and a lateness rule. This will include long runs in an attempt to achieve steady-state conditions for all priority rules, and sufficient replications to permit formal tests for members of set R.
2. An analytical study of priority rules, including a condition for membership in set R.
3. A more extensive investigation of the relationship between utilization and work-in-process inventory.
4. Tests to determine the significance of:
   a. changes in shop size.
   b. unbalance of load among machine groups.
   c. imperfect prediction of processing times.
   d. changes in value distribution and operation time distribution.
5. Study of the prediction of individual job completion times; an attempt to relate completion time to job characteristics under various decision rules.
6. Study of the relative effectiveness of priority rules as compared to longer-scope planning procedures for the same function.

This is a preliminary report and has probably suggested more questions than it has answered. We would welcome any comments and suggestions.

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Industrial Engineers, Incentive Systems, and the Contract

by **CHARLES A. WERNER**

Stockham, Roth, Buder and Martin, St. Louis, Missouri

I'll call you if we get into a wrangle over the incentive section of the contract during negotiations!

I think we will have to arbitrate the grievance on the incentive rate for the No. 2 Mill. Bring in your notes and we will go over them together and see what can be done!

THESE statements exemplify the type of relationship that exists between many Industrial Engineers and other members of the management team. It is a relationship wherein the Industrial Engineer is called if negotiations break down or if a dispute arises regarding some phase of Industrial Engineering activities. Frequently, it is too late to do anything very constructive. Either the positions have solidified at the negotiating table, or an inadequate foundation has been laid in the contract for settling the dispute which is now at the arbitration stage. The only solution in both examples is compromise; a compromise at the negotiating table, and a compromise by taking the dispute to arbitration and having an impartial outsider interpret or apply the contract.

Arbitration plays a vital role in the field of labor relations; however, the maximum results are obtained if a sound foundation has been laid which either prevents incentive disputes from arising or supplies the answer if a dispute does develop. While, this is an idealistic approach, it should be the objective of every management team.

The irony of this whole situation is that in most instances the incentive is technically correct and meets all of the requirements of sound Industrial Engineering principles. The trouble appears to be that the Industrial Engineer has not applied (or been allowed to apply) the same sound planning he used in developing the rate, toward coping with the complex problems which are the result of an inadequate collective bargaining agreement.

The Industrial Engineer has either overlooked or never really appreciated how dependent his activities are upon the collective bargaining agreement. He generally accepts the contract as is and plans his activities upon that basis. Frequently, he states that the contract belongs to another part of management over which he has no control or influence. Whatever the reason, or lack of reason, the Industrial Engineer has not entered the collective bargaining picture early enough to provide the background and technical information that is needed to build a solid incentive structure.

What is needed is teamwork and understanding—teamwork between the Industrial Engineer and the negotiating team in the preliminary stages of contract strategy and preparation—understanding of what is wanted and the manner in which the contract should be written to achieve the desired objectives. On this foundation, management can obviate potential incentive problems.

This article, therefore, is a general discussion of some of the contractual points and problems which an Industrial Engineer must consider and understand so that his incentives obtain maximum effectiveness. Mention must also be made of the fact that the article only deals with general considerations and not specific company and industry applications. It would be hopeless to even attempt to consider *all* of the ramifications of handling incentive provisions in a collective bargaining agreement.

Basically there are three points (or questions) which the Industrial Engineer must take into consideration.

1. Are incentives subject to collective bargaining?
2. What type of incentive structure is needed in the plant?
3. How can the contract be worded so that the incentive structure is expressly set forth in the contract, and at the same time eliminating the ambiguous statements and incomplete phrases which bring about the later disputes and arguments?

The second point (or question) will not be discussed in this article. It is only to the first and third question that we turn our attention.

COLLECTIVE BARGAINING

The National Labor Relations Board holds that incentives are considered to be wages and subject to collective bargaining. This has been a consistent holding of the Board for the past two decades. A refusal to bargain over incentive systems is thus an unfair labor practice and a violation of either section 8(a)(5) or 8(b)(3) of the Labor-Management Relations Act (1). This does not mean, however, that the employer must agree with the union, or to concede to the union on disputed points. All that is meant is that the employer must sit down with the union at the negotiating table and to discuss in good faith

the provisions relating to the incentive system. As expressed in section 8(d) of the aforementioned Act:

> (d) For the purpose of this section, to bargain collectively is the performance of the mutual obligation of the employer and the representative of the employees to meet at reasonable times and confer in good faith with respect to wages, hours, and other terms and conditions of employment, or the negotiation of an agreement, or any question arising thereunder, and the execution of a written contract incorporating any agreement reached if requested by either party, *but such obligation does not compel either party to agree to a proposal or require the making of a concession:* . . . (emphasis added)

The National Labor Relations Board has, by its decisions, clarified the area of what is or is not bargaining in good faith, and thus what is or is not an unfair labor practice. It has held that an employer may neither initiate (2) nor abolish (3) an incentive wage plan without bargaining with the union over such action. It has also held that if the company makes changes in an existing plan, it must afford the union the opportunity to go over the time studies which are the basis of the changed rates (4).

The holding that incentive systems are subject to collective bargaining, raises a related question of what data or information must be made available to the union. In the *Otis Elevator* case (5), the Board held that the company must make available to the union certain time study data in its possession which were used in developing the standards. The Board also held in that case that the company had to permit the union to use its plant to make an independent time study. The Court of Appeals for the Second Circuit in *National Labor Relations Board versus Otis Elevator Co.* (6), enforced that part of the Board's order dealing with the data but denied enforcement of the order permitting the union timestudy man to come into the plant. In a recent case, *J. I. Case Co.* (7), the Board held that bargaining is a continuing matter and that it is an unfair labor practice for an employer to refuse to give time study data when requested by a union in good faith to *administer the contract*. This means that the data must be supplied throughout the term of the contract and not just at negotiation time. In the *Tree Fruits Labor Relations Committee* case (8); the Board summarized its holdings in this area of the law:

> It is well established that where the information requested by a bargaining agent consists of wage data it is the employer's obligation to provide such data as is relevant for the purpose of administering a collective bargaining agreement or for collective bargaining purposes, where compliance with such a request would not be unduly burdensome.

CONTRACTUAL PROVISIONS

Contractual provisions relating to incentives and incentive arbitration procedures must be tailored to the specific needs of a company. In addition, most companies have past practices and precedents which must be taken into consideration. These practices and precedents, however, do not preclude the adoption of new provisions or the revision of old ones. As discussed earlier in this article, incentives are a collective bargaining item. To this extent, new and change provisions can be proposed for adoption into the collective bargaining agreement.

Basically, there are six major points which a company should consider when either reviewing or incorporating contractual provisions relating to incentives. These points are mentioned because they have been the subject of many arbitrations as the result of ambiguous and inadequate contractual language.

1. Purpose of and right to install the incentive system.
2. Procedure for establishing the incentive rates.
3. Basis for making incentive rate changes.
4. Wage policy as affected by incentive guarantees, training periods, etc.
5. Effect of spoiled or substandard work, and failure to meet production levels.
6. Procedure for solving incentive disputes.

PURPOSE OF AND RIGHT TO INSTALL THE INCENTIVE SYSTEM

The Bureau of Labor Statistics defined a wage incentive plan as (9):

> . . . a method of wage payment by which workers receive extra pay for extra production. In establishing wage incentive plans, consideration must be given to (1) the base rate for the job, (2) the amount of work required to earn the base rate, and (3) the relationship between extra work above the base and extra pay for the extra performance.

Briefly, it may be expressed as a system whereby *extra skill and effort* on the part of the *employee* resulting in *increased production* will be compensated by additional *wages*. A statement setting forth the compensating factors and purpose for having an incentive plan should be included in the incentive section of the contract. Such a statement is no different than the "purpose" statement which is usually inserted at the beginning of the collective bargaining agreement, and in times of dispute, the parties to the contract can refer to it for aid in solving the problem.

One noticeable instance where an incentive plan "purpose" statement will be of value is when increased productivity has resulted solely from the usage of improved equipment. The question is raised: "Who is to receive the benefits of such increased productivity—the company or the employees?" If such a statement is included in the contract, it will inform the arbitrator of the purpose of the incentive plan. He will then be on a sound foundation for ruling in favor of the company and ignoring the union's demand for "maintenance of prior earnings."

Another point which will aid in eliminating potential trouble, is to include a statement in the contract to the effect that management has the right to determine *on which operation* the incentive will be placed.

PROCEDURE FOR ESTABLISHING THE INCENTIVE RATES

Union participation in incentive rate making varies among unions and industries. There are some union repre-

sentatives who will have nothing to do with an incentive rate until it is issued and given a trial run. On the other hand there are other unions, such as those in the apparel industry, which negotiate on all rates and agreement is necessary before any rate may be effective.

One national organization (10) which summarizes collective bargaining provisions estimates that about one-half of the agreements in manufacturing industries include some reference to piece work or incentive pay operations. Of these contracts with incentive clauses, union participation in setting new rates may be broken down into three basic types:

1. The company has full control over determination of rates, subject only to grievance action by the union after the rate is put into effect 60%
2. The union is consulted in advance but the company retains the right to institute the rate even without approval, subject to subsequent union grievance 25%
3. The union negotiates on all rates and its agreement is necessary before any rate may be effective 15%

There is varied opinion as to the amount of detail which should be included in the contract regarding the procedure for establishing the incentives. Some companies, such as International Harvester, go into great detail in outlining the procedure for setting the rates. A few companies lean the other way and only include a passing reference that the company will follow past practices in setting rates. Still other companies follow policies which come in between the practices of the above extremes. These companies specify that the methods and procedures used in setting the incentive rates will be consistent with recognized engineering practices.

No matter what language is incorporated in the contract, the guiding principle should be a flexibility for using the procedure best suited for the operation. Thus, a company should not find itself tied down to individual time studies, when standard data, MTM, or some other procedure would be more practical and efficient.

There is another point which should be mentioned when discussing the procedure for establishing incentive rates. This concerns the advisability of including a "trial period" for new or revised rates. In my opinion a trial period is desirable. It allows the employee an opportunity to work on the rate and to determine for himself whether he will be able to make additional wages through incentive efforts. A trial period also benefits the company. It shortens the period of unrest, and if there are no grievances during the period designated, the rate will be presumed approved and accepted. Care should be taken, however, in setting a trial period which is workable and does not have the effect of placing a burden on the company. For instance, a 30-day trial period might be adequate in some plants, but in other plants with variable job orders, the rate might be worked on only twice during a 30-day period. To handle this problem, the trial period clause should provide for 15 *working days on the new or revised rate.*

BASIS FOR MAKING INCENTIVE RATE CHANGES

Perhaps the most arbitrated clause in the incentive section of the contract is the clause allowing revision of incentive rates if there is a change in working conditions. The grievances generally arise because either there is incomplete coverage in this section relating to possible changes, or there is a dispute over what is meant by certain words in the contract. For instance, what is meant by a "substantial change (11)?" Are changes in feeds and speeds a change in methods or working conditions (12)? What about changes in weight (13)? Many of these problems can be prevented by a more complete statement in the contract. One such statement suggested by Irving Delloff in his fine article, "Incentive Clauses: The Costly Clinkers," is as follows (14, p. 54):

> Standards of production will not be changed unless there has been a change in the methods, materials, equipment, feeds, speeds, quality requirements, or any other conditions under which the original standard was established. Only the element that is changed, and other elements that may have been affected, will be recalculated. Standards may also be changed when clerical errors in computation are found.

This clause will cover many of the problems that might arise regarding changes in the operation. In the first place, it includes most of the possible changes which can occur. But then it goes on to make it all-inclusive by saying "or any other conditions under which the original standard was established." Second, it covers the problem of re-timing. Should the whole operation be re-timed, just the changed operation, or the changed operation *plus* the affected operation? It should be mentioned that some companies prefer to re-time the whole operation. Other companies, particularly those using standard data, may prefer the provisions of the above clause, that is, re-timing only the changed and affected elements. Third, the clause covers those instances in which there has been a clerical error. The errors referred to, however, are mathematical or clerical calculations and not errors in the analysis and application of the time study figures (15).

Some labor relations personnel believe that disputes will be avoided and grievances eliminated if the language in the contract is "substantial change" and not just "change." It is asserted that "substantial" has only one meaning. Unfortunately, this is not true. Reasonable men *can* differ on what is meant by the word "substantial" and arbitrations do arise (*Veeder-Root, Inc.*) (11). There are others who extend this reasoning further and admit the potential trouble, but state that this is the only way to avoid taking numerous time studies to hold down the so-called "incentive creepage." These points are well taken, and a company might do well to balance these potential trouble areas. There is another method of handling "incentive creepage" which is infrequently used, but which I feel to be worthy of mentioning. This consists of negotiating a clause which provides that the in-

centive rates shall be reviewed and/or restudied every six months (or any other predetermined length of time). Periodic reviews will benefit the company by holding down the "incentive creepage," and at the same time assist the union by eliminating employee bickering and charges of favoritism. Care should be taken so as not to preclude the immediate retiming of major changes.

What happens when the "change" is initiated entirely by the employee? Should he be allowed to retain the benefits of his ingenuity and initiative, or should the improvement fall under the "change" clause just like any other change in methods? Owen Fairweather feels that "employee-invented method changes" should be revised like any other change, since otherwise there will be a premium placed on the presentation of false motions to the Industrial Engineer when the employee is being timed (17, p. 78). I concur with Mr. Fairweather's philosophy of revising all changes no matter who initiates them. However, in my opinion, cash settlements should be given to those employees who actually improve their operation through ingenuity and mechanical skill. Such a settlement would be based upon a predetermined percentage of the first year's savings on the job. Under this plan, the incentive rate is revised because of the change in operations, the employee is rewarded for his extra efforts, and the new method is applied on other operations throughout the plant.

There is still another difficult problem which arises within this realm of incentive rate changes. This problem concerns those operations which when originally timed included legitimate idle time or machine-wait time. The rate was set accordingly, and now the company is either attempting to eliminate this time, reduce it sharply, or add another machine to be operated by the employee. How should the new rate be set? One would not argue the point if the increase in time eliminated the wait time and increased the overall time of the operation. Then the rate should be increased. But on the other hand should the company have to tolerate an incentive rate increase if a machine and hand operation is revised so that an additional element is added during the machine-wait portion of the cycle? I think most Industrial Engineers will agree that the rate should not be increased in such a situation. The necessity of setting a rate in the beginning which includes machine-wait time should not penalize the company at a later date.

The question then becomes, how can this be incorporated into the contract? Two possibilities exist. One solution would be the insertion of a clause which states that the intent of the parties is that there will be a "ratio of earnings to effort expended." A second solution would be to expressly provide in the contract that: a. machine elements in an equipment paced operation will be leveled at maximum incentive effort, and b. internal elements within that machine time, will not affect the overall time allowance of the operation.

WAGE POLICY AS AFFECTED BY INCENTIVE GUARANTEES, TRAINING PERIODS, ETC.

One frequent trouble spot in the incentive section is the provision stating the capabilities of the incentive plan. If care is not taken the words of the contract can obligate the company to a fixed and unrealistic incentive level. For instance, the contract should *not* say "shall achieve 125% of standard for incentive effort." The word "shall" in that sentence would compel the company to pay all of the workers a minimum of 125% incentive. What the company should say is "the average worker, working at an incentive pace, *will be able to average* 25% incentive earnings over a period of time" (such as three months). The latter phrasing is realistic, in that it establishes an incentive pay schedule which is consistent with the Industrial Engineering methods used to develop the rate. At best, leveling is a combination of art and science. Studies have shown that Industrial Engineers are able to achieve a 5% accuracy in their leveling over a period of time. Therefore, any incentive plan using leveling should recognize this fact and it should be incorporated in the contractual language.

Many disputes arise over questions of pay during training and experimental periods, and when unavoidable delays occur. While the usual procedure is to include allowances for unavoidable delays in the total incentive rate, there are instances when this is not practical or the delay is of a long duration. The question then arises as to what the employee should be paid during these periods of time. Should it be base rate pay, average incentive pay, or some combination of these two? While some arbitrators (18) maintain that the obligation to pay anything but base rate pay does not arise in absence of contract language to that effect, it would seem preferable to prevent this potential problem with a specific provision in the contract. Such a provision, however, must be consistent with usage of terms in other sections of the contract, otherwise trouble will be created instead of prevented (19).

EFFECT OF SPOILED OR SUBSTANDARD WORK, AND FAILURE TO MEET PRODUCTION LEVELS

Relatively few contracts deal specifically with the problem of spoiled work or for the failure to meet standard production levels. This, however, can be an area of dispute, and some mention should be made in the incentive section. Mr. Delloff in his article suggests two provisions which cover these areas (14, p. 53):

> The guiding principle in paying for production on incentive will be that a bonus will be paid for production of acceptable quality only. The Company shall be the sole judge of what constitutes acceptable quality. The employee will not be penalized where work is rejected through no fault of his own. If, however, an employee produces work of substandard quality he will be required to repair or rework the substandard work at the discretion of his superior. Moreover, work of substandard quality will be deducted from the total amount produced by that employee and

incentive will be calculated for good work only. At no time shall an employee receive less than his base rate.

The Company shall have the right, without interference from the union, to discipline employees whose productivity is consistently below standard. An operator who is consistently below standard shall be defined as an operator whose average weekly productivity falls below standard for any two weeks in a month.

PROCEDURE FOR SOLVING INCENTIVE DISPUTES

An important phase of the incentive system is the procedure incorporated in the contract for settling disputes that may arise. The main point which should be considered in setting up such a procedure, is to bring in the people involved as soon as possible. For this reason, it is probably best to have a separate grievance procedure for incentive disputes so that the procedure is geared for the Industrial Engineers instead of the production supervisors. A set-up for a large plant might be as follows: 1st step—Time Study Man and Foreman; 2nd step—Time Study Department Head; 3rd step—Director of Industrial Relations; 4th step—Plant Manager; and 5th step—Arbitration. Workable time requirements should be provided for each of the aforementioned steps.

The question of who should arbitrate incentive disputes should not be designated in the contract. If the dispute is technical in nature, it is advisable to have an Industrial Engineer as an arbitrator, or a lay arbitrator with an Industrial Engineer as a technical advisor. If, however, it concerns interpretation and application of the contractual language, then it is probably best to have a lay arbitrator. Owen Fairweather expressed it very well when he said (17, p. 64):

> The belief that since incentive standards are established by industrial engineers they must be arbitrated by industrial engineers, though it may seem reasonable on the surface, reveals a very fundamental weakness. If management believes that it cannot convince an impartial arbitrator who is not an industrial engineer of the fairness of an incentive standard, it is admitting that it cannot convince just an ordinary fair-minded person that an incentive standard it has established is fair. If that is true, how can it convince one of its employees, or the union leader, none of whom are trained industrial engineers, that a standard it has established is fair?

There are a few companies who have endeavored to place limitations on the arbitration of incentive grievances. These companies reason that since incentives are wages, an arbitration of a rate is equivalent to reopening the contract. That this is basically true, is not to be denied. However, it is questionable whether the principle involved herein justifies the suspicion generated when the employees are denied the procedural outlet for questioning incentive rates. Frequently, the point is not the use of the arbitration procedure, but the fact that it is *available for use* if the union desires to take an incentive grievance to arbitration.

Here is one further point regarding incentive arbitration limitations. If such a limitation is negotiated with the union, the wording must be carefully chosen otherwise the effectiveness of the limitation will be considerably reduced. An illustration is the recent *IUE versus Westinghouse* case (20). In that case the union had filed two grievances:

> 1. The union objected to the company's assignment of a different time value to a new part, which was different from an existing part in *width* only.
>
> 2. The union objected to the company's method of reducing the time value for a certain manufacturing operation after a portion of that operation had been discontinued.

Both grievances went through the preliminary grievance steps without settlement, and the union requested arbitration. The company refused citing the following contractual provision:

> D. Nothwithstanding any other provision of this Agreement, no arbitrator shall, without specific written agreement of the Company and the Union with respect to the arbitration proceeding before him be authorized to:
>
> (2) Establish or modify . . . any time value under the incentive system.

The union brought suit in the United States district court to enforce arbitration under Section 301 of the Labor Management Relations Act, 1947. The court sustained the union and directed arbitration. On appeal, the court of appeals affirmed the lower court's decision. The court was careful to point out that the arbitrator's task would be to determine whether there was an existing time value for the particular operation. The court said:

> In reaching these conclusions the arbitrator would neither be establishing new time values or modifying the present ones. He would be merely declaring what the particular actual time value situations are by correct interpretation of the existing written collective bargaining agreement.

Thus, the court reduced the effectiveness of the arbitration limitation by its interpretation that the contractual limitation did not include the determination of the applicability of an existing time value.

One of the most active issues in the Labor-Management field, is the issue briefly referred to in the previous paragraph. That is, if one party refuses to arbitrate a dispute which that party contends is not arbitrable, who, if anybody, is to determine the arbitrability of the grievance? Basically the issue of arbitrability depends upon the interpretation of the contract. If the contract provides that either the arbitrator or the court is to decide the issue, then that is the manner in which arbitrability will be determined. In the absence of such an express provision, the federal courts are in general agreement that where a suit to compel arbitration is brought under Section 301 of the Labor-Management Relations Act, 1947, as amended, the federal district court must determine for itself whether the grievance is arbitrable under the contract (21). The Act also vests in the federal district court, inter alia, the power to decree specific performance of the arbitration clause in the contract (*Textile Workers versus Lincoln Mills*) (22). Following the *Lincoln Mills*

case, there has been an expanding influence of the courts in the realm of arbitration and the enforcement of contract provisions. However, space does not permit more than this brief mention of a potential problem area.

CONCLUSION

This author contends that the Industrial Engineer and other members of the management team, have not appreciated or recognized the overall factors and interdepartmental relationships upon which the success or failure of an incentive system may depend. In the past the main emphasis has been on the technical aspects of the incentive, with the Industrial Engineer being brought into the labor relations picture *after* a dispute has arisen. The collective bargaining contract has been virtually ignored as a tool in securing a sound foundation for the incentive system, and for obviating probable disputes.

The purpose of this article has been to discuss, on a general level, the main points and problem areas which one encounters in working with incentive systems. The author asserts that an understanding of these areas together with better teamwork at the negotiation stage of the incentive system, will result in a more effective collective bargaining structure and, a fortiori, a more effective incentive system.

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A Method for Correcting Errors in Time Study Practice

by **KEVIN ENNIS**

Ford Motor Company
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IN RECENT years, there has been plenty of healthy airing in what concerns the basis of time study rating. Particularly noticeable, Gomberg's (3) and Davidson's books (2) have pointed out the many weaknesses of present practices. In Argentina, Mr. Tore Bergsvik's classes and lectures have often done a similar job.

However, those weak practices have survived in plants throughout the world, for one chief reason: no improvements have been forthcoming. Time study rating, though practiced with slightly different systems and assumptions by different schools of engineers, is still, in the main, a more or less educated guess.

This paper's object is to try to improve the "education" of the guess. Even when done with the method outlined here, rating will still be, at heart, a guess. But our purpose is, at least, a more polished guess.

The method proposed is born out of a brief analysis of the different types of errors that may appear during the rate-setting process. Introducing some assumptions, a simple mathematical model is built, and from this, a procedure is developed to help the rater to correct some of the errors present.

THE RATING MECHANISM

Different Industrial Engineering schools or systems, propose different assumptions and different methods for establishing the value of a number with which the observed cycle times are corrected in order to obtain a standard. Some use a single number, based on an estimate of "tempo," or of "speed," or of "effort," or of "pace," etc.; others suggest the use of several numbers, one for each of a series of "factors"; etc. However, we will avoid discussing these aspects here. We will reduce the problem to fixing one value, V, a dimensionless number; and we shall observe those values already fixed, regardless of the method or assumptions used to obtain them.

For a given cycle of a given job, variations in cycle times, T, should cause variations in the rating value V, so that the "standard" or "normal" time remains constant. Thus, V must obey a law of the type:

$$T \cdot V = \text{constant} \qquad \text{Eq. 1.}$$

in which the value of the constant depends on the job, the units used, etc. Also, if we use a value of V 100 for the "normal" rate:[1]

$$T_1 \cdot V_1 = T_2 \cdot V_2 = \cdots = T_i \cdot V_i = \cdots = S^* \cdot 100 \qquad \text{Eq. 2.}$$

in which S^* is the standard, or "nomal" time value, which we are trying to establish by giving weights V_i to the observed times T_i.

The positive branch of an hyperbola referred to its asymptotes taken as axis is the geometrical locus of the set of pairs of points T_i, V_i thus defined. In Figure 1, curve $A1$ illustrates this traditional relationship between time values and rating values.

RATING ERRORS

However, in actual practice, Eq. 2. very seldom holds for more than two or three values, if any. That is, in spite of the observer's desire, his several ratings are seldom consistent. This is because of the different errors present.

Firstly, this is a kind of "measurement." As such, we might expect some kind of random distribution of values of Ve (Values estimated) for each T_i. This happens even in measurements where an objective and clearly defined

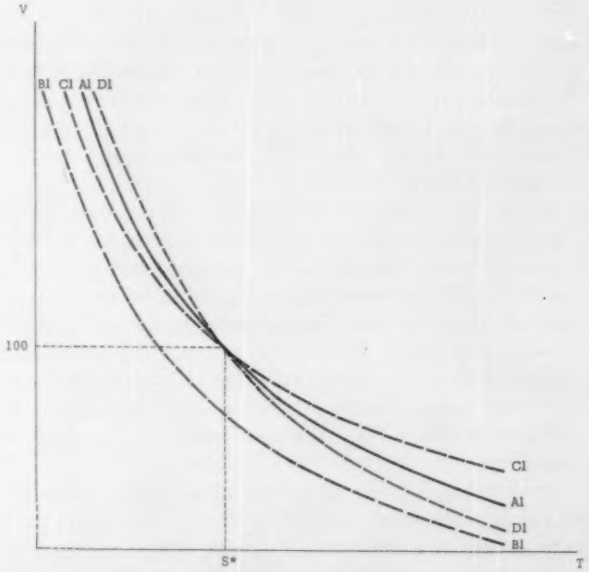

FIG. 1

[1] The base value of 100 has been chosen for simplicity's sake. If 60, or any other value were chosen, the results would be basically similar.

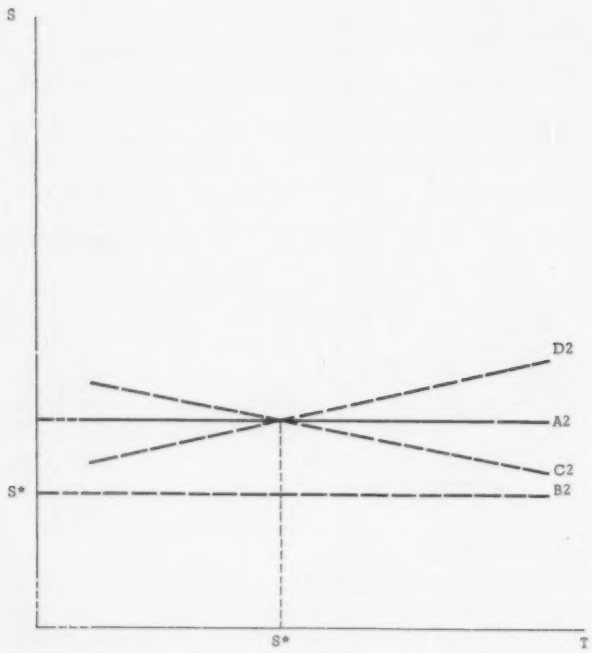

FIG. 2

unit exists, so it is reasonable to expect the same to happen here, where we lack those advantages, and where we are not even sure about how to define what we are measuring. This effect should cause a scatter around the curve $A1$.

Secondly, there might exist a biased error. Maybe the observer has rated too high, or too low. This would cause a curve such as $B1$, in which case the observer has always rated 25% over the correct value. When the bias is of the same relative magnitude over all the range of observations (such as $B1$ illustrates) we shall call the error "uniformly biased."

In the third place, there might be a bias of varying influence. Of such type are the errors caused by a "conservative" rater, who rates lower than right when the time value is small and rates higher than right when the time value is big. This effect is illustrated by curve $C1$. Also, the opposite defect, caused by exaggerating the rating values; higher than right, when the time value is short, and lower than right when time value is long. This is illustrated by curve $D1$. We shall refer to this type of biased error by the words: "cross-biased."

Other errors are introduced by rounding the values for Ve_i. It is a frequently found habit to use, for rating purposes, only such values as 110, 115, 120, etc., that is, figures ending in 0 or in 5, avoiding the use of values such as 114, 117, etc. The same occurs when 60 is used as base value.[2] This introduces some error, due to grouping, which if necessary, could be corrected by use of an adequate statistical method. We shall neglect these errors here.

Another type of error may be incurred by not choosing a time value which is representative of observations made. Though more research is necessary on this point, it usually seems to be that observation of one cycle is not enough for the observer to make up his mind on a value. Thus, if he has observed n consecutive cycles and has arrived at a value Ve, should he level the arithmetic mean of these n time values, or should he level the mode—that is, the most frequent value, which might be considered as the one that impressed him most? Or should he use the median, or the harmonic mean? This is an unknown error which we shall neglect here.[3]

We are also setting aside any discussion about effects of slight variations in the method used by the operator.

The nature of the influence of these several types of errors is more clearly seen if we use a different type of graphic representation. From each pair T_i, Ve_i, the observer might compute a standard, or "normal" time, S. Due to the influence of errors, Eq. 2. is not valid, and we shall, in general, have different standards, one for each pair. To identify each of these, we shall write S_i. Therefore, using base 100, we have:

$$S_i = \frac{T_i \cdot Ve_i}{100} \qquad \text{Eq. 3.}$$

If we plot the values of S_i against T_i, we obtain a chart such as Figure 2. Here, line $A2$ is the result of the situation illustrated by curve $A1$ in Figure 1. These are the theoretically correct results; the observer has consistently rated all observed times, so that he always has obtained the same standard, S^*.

Line $B2$ is the equivalent of $B1$. The observer has always overrated by 25%, and, though his values are consistent, there is a "uniformly biased error" present.

$C2$ and $D2$ illustrate "cross-biased errors." The values given to V are not consistent, so different standards are obtained, according to how long the cycle lasted. Both these lines cross the theoretically correct value at a point corresponding to "normal" time. When "cross-biased errors" have this property of cutting the correct value at the point corresponding to the "normal" time, we call them "normally cross-biased errors." It can be shown that any non-normally cross-biased error may be broken into a "uniformly biased" error plus a "normally cross-biased" error. The reader can easily check on this by drawing those error lines on a chart similar to Figure 2.

In ordinary time study, the "normal" value is unknown. If we plot the results of such a study on a chart

[2] This habit is generally based on the quite reasonable assumption that an observer cannot distinguish finer differences than those calling for increments of 5. In this sense, however, it is interesting to observe that users of base value 100 have a stricter requirement than users of base value 60, because in this latter system a difference of 5 represents a wider range than in the former.

[3] However, when we mention a time value T_i paired with a rating value V_i, it is understood that T_i stands for the value chosen as representative.

of this type, we obtain a series of points to which a line may be fitted. If this line is fitted by the minimum squares method, we can correct the effect of scatter due to the random errors mentioned in the first place. We cannot, however, determine nor correct the value of a "uniformly biased error"; we cannot even tell if such an error is present or not. But what will show up, and can therefore be corrected, is any "normally cross-biased error."

ASSUMPTIONS

We have already outlined the essence of the method, which is really a check on consistency of rating values. It may be convenient to review some of the main assumptions involved, before going into more detail.

1. The observer does not place faith on a single rating. Either several time studies are made, with a rating for each, or the study is divided into several parts with their corresponding rate estimates. Some people rate each cycle. As far as this method is concerned, this is also feasible.[4]

2. We dismiss uniformly biased errors. Against them, this method is powerless. These errors are what make rating a matter of guessing.

3. All cross-biased errors are assumed to be normally-cross biased. This is not so unreasonable as it sounds, because:

   a. It is generally recognized that trained observers have less difficulty in correctly identifying "normal pace" when they see it. That is to say, there is a small range of relatively "safer" rates around "normal", for which agreement is easier.

   b. This assumption does not pretend that any time marked "normal" by the person using this method is automatically considered as the standard time, regardless of other observations and estimates. On the contrary, we admit the existence of an unknown[5] distribution of the values to which the observer will give $Ve = 100$, that is, of the values labelled "normal". This method boils down to a trick by which an observer can widen the number of "safer" observations by correcting the type of error which reduces the "safety" of the rest of the observations. Also, it might be applied when the only observations available are of the "not-so-safe" levels, that is, when no observations of near normal rate have been made.

   c. It may be easily proved, both analytically and graphically, that any non-normally cross-biased error line is the result of the sum of an uniformly biased error, plus a normally cross-biased error. Uniformly biased errors pass by undetected by this method, which does not pretend to cope with them.

4. Cross-biased errors obey a simple, linear law. In some cases, it might be expected that the line fitting the points should be a curve of higher grade. The assumption of linearity might be tested by statistical computing (4, p. 535). However, we shall dismiss more complicated types of relationship, believing that the conditions of the problem at present do not warrant a more involved treatment.

5. Time value observations are correct. We neglect timing errors here.

On the strength of these assumptions, S^*, the standard time, might be chosen. This value will lie on the intersection of the line fitted to the points determined by the pairs T_i, S_i, and the line $T = S$, which is the locus of the time values T which receive a rating $V = 100$. This, because the fitted line describes the trend the observer's errors have, and the spot where this trend line gives us a value for $V = 100$ is, because of our assumptions, the "safest" estimate.

ANALYTICAL EXPRESSION FOR S^*

If the error present in the rating is normally cross-biased, the observer will give each T_i a rating estimate Ve, such that:

$$Ve = Vr + \alpha(100 - Vr) \qquad \text{Eq. 4.}$$

Vr is the real rating that would be given if no cross-biased error were present; α is a factor, which as later shall be shown, is the tangent of the angle between the fitted line and the T-axis. When α is positive, our observer is conservative, softening his ratings as they stretch apart from normal, tending to give them values nearer to normal; if α is negative, our observer is exaggerated, tending to make the difference from normal greater than necessary. If α is null, the observer has been consistent in his ratings, and no influence of the length of time on the rating value is to be noticed.

As Vr is the real rating, we have $Vr_i \cdot T_i = \text{constant} = S^* \cdot 100$, and therefore,

$$S^* = \frac{T_i}{100} \cdot Vr_i \qquad \text{Eq. 5.}$$

On the other hand, we have that the estimated S_i shall be:

$$S_i = \frac{T_i}{100} \cdot Vr_i \qquad \text{Eq. 6.}$$

And, replacing Ve_i by it's value according to Eq. 4., and using Eq. 5. to simplify, we have:

$$S_i = \frac{T_i}{100} \cdot Vr + \frac{T_i}{\cancel{100}} \cdot \alpha \cdot \cancel{100} - \frac{T_i}{100} \cdot \alpha \cdot Vr$$

$$= \frac{T_i \cdot Vr}{100}(1 - \alpha) + \alpha \cdot T_i$$

$$\therefore S_i = S^*(1 - \alpha) + \alpha T_i \qquad \text{Eq. 7.}$$

We can consider S_i and T_i as continuous variables, related by a linear function; to show this we may suppress the suscripts i, and write:

$$S = S^*(1 - \alpha) + \alpha T \qquad \text{Eq. 8.}$$

We want to fit a regression line of the form $S = a + b(T - \overline{T})$, by the method of least squares. By simultane-

[4] It is nowhere assumed that only one observer is involved, though the word "observer" has been used in singular. Several raters might pool their estimates, thus driving toward greater consistency throughout studies made by different members of the time study department.

[5] It is unnecessary to make any assumption about the nature of the distribution of the Ve for each T_i. The least square estimate is the "best" estimate—that is, unbiased and of minimum variance—even when the distribution of the dependent values for each independent figure is not a Gauss curve. This is proved by Markoff's theorem, see some statistical text, such as (4, p. 584), or (1, p. 554).

ously adding and subtracting $\alpha \cdot \overline{T}$ (where $\overline{T}$ is the arithmetic mean of the T_i) from Eq. 8., we obtain:

$$S = \underbrace{S^* + \alpha(\overline{T} - S^*)}_{a} + \underbrace{\alpha}_{b}(T - \overline{T}) \qquad \text{Eq. 9.}$$

in which we have pointed out the values corresponding to the parameters a and b. It can be seen that α is the value of parameter b in the regression line, and is thus the value of the tangent of the angle formed by the regression line and the T-axis. The value of a, if the least squares method is used, is (4, p. 538)

$$a = \overline{S} \qquad \text{Eq. 10.}$$

where $\overline{S}$ is the arithmetic mean of the S_i. The value of b is:

$$b = \alpha = \frac{\sum (T_i - \overline{T})S_i}{\sum (T_i - \overline{T})^2} \qquad \text{Eq. 11.}$$

Remembering that the independent constant in Eq. 9. is the value of a, and using Eq. 10., we have:

$$a = \overline{S} = S^* + \alpha(\overline{T} - S) = S^*(1 - \alpha) + \alpha\overline{T}$$

$$\therefore S^* = \frac{\overline{S} - \alpha\overline{T}}{1 - \alpha} \qquad \text{Eq. 12.}$$

By replacing the value of α given by Eq. 11. into this last expression, we obtain:

$$S^* = \frac{\overline{S}\sum (T_i - \overline{T})^2 - \overline{T}\sum (T_i - \overline{T})S_i}{\sum {}_BT_i - \overline{T})^2 - \sum (T_i - \overline{T})S_i} \qquad \text{Eq. 13.}$$

This quite complicated expression is the value of the standard time, as corrected for normally cross-biased errors and random "measurement" errors. This value, however, might be more easily obtained by graphical means. One way, is to compute $\overline{S}$ and $\overline{T}$. The point corresponding to this pair of values belongs to the regression line, because these values are the arithmetic means of both variables, and because the regression line fitted by the least squares method passes through the point defined by both averages; if they are equal, that is, if

$$\overline{S} = \overline{T} \qquad \text{Eq. 14.}$$

we know that this point belongs also to the locus of times with normal rating, and therefore, it is the point of intersection of these two lines, that is the value S^* for which we are searching. If Eq. 14. does not hold, we compute α by means of Eq. 11., and then draw a line passing through the point $\overline{S}$, $\overline{T}$, with an inclination of tangent equal to α. We also draw the line $S = T$, and in the point where both lines cut, we have the value of S^*.

This method, though simpler than the analytical, is still rather involved for everyday use.

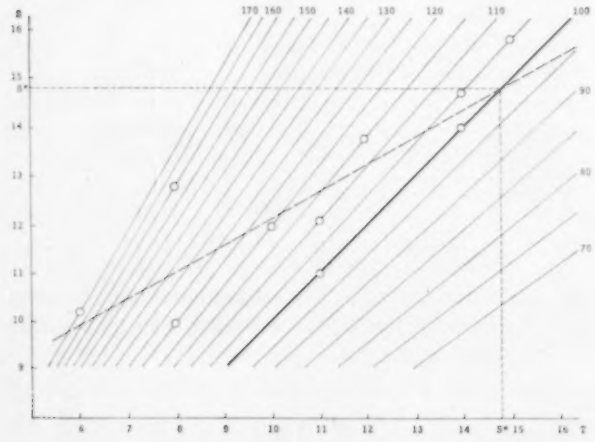

FIG. 3

SIMPLE GRAPHICAL PROCEDURE

It has been mentioned that the line $S = T$ is the geometrical locus of the points with $Ve = 100$. From Eq. 3., if we give Ve a fixed value, lets say Ve^*, we obtain:

$$S = \frac{Ve^*}{100} \cdot T \qquad \text{Eq. 15.}$$

which is the equation of a line that passes through the origin of coordinates, with an inclination angle of tangent equal to $\cdot 01.Ve^*$. This line is the locus of all points with rating value Ve^*. By giving Ve^* values of 105, 110, 115, 120, etc., and 95, 90, 85, 80, etc., we obtain a family of lines which we may plot on our chart. The result is illustrated by Figure 3, on which are plotted some points corresponding to an example that will clear up the question.

After observation, we have a set of pairs of values for T_i and Ve_i, such as the following, for example: (time in hundreths of minute)

$T_1 = 15$; $Ve_1 = 105$	$T_6 = 14$; $Ve_6 = 100$
$T_2 = 8$; $Ve_2 = 160$	$T_7 = 6$; $Ve_7 = 170$
$T_3 = 11$; $Ve_3 = 100$	$T_8 = 12$; $Ve_8 = 115$
$T_4 = 8$; $Ve_4 = 125$	$T_9 = 14$; $Ve_9 = 105$
$T_5 = 11$; $Ve_5 = 110$	$T_{10} = 10$; $Ve_{10} = 120$

To plot these points, for example, T_1, we first find the value $T_1 = 15$ on the T-axis. From there, we travel upwards until we cut the line for $Ve_1 = 105$. The point of intersection is the point we must plot.

When we have plotted all our observations, we visually fit a line and read the value of the point where this line crosses the line for $V = 100$ (which is the $S = T$). This value is the standard, S^*, corrected for normally cross-biased errors and for random "measurement" errors. In Figure 3, we see that for this example $S^* = 14 \cdot 8 \simeq 15$.

It is to be noticed in this example that the two time values labeled "normal" by the observer are both under the value chosen for S^*. This, in spite of assumption 3, shows how we do not accept only the values with $Ve = 100$ as basis for our method. It may be also seen that the

use of some type of average, say $\bar{S}$ for example, as an estimate of S^*, is theoretically incorrect.

For ordinary use, ruled charts like that in Figure 3 might be obtained already printed.

As a by-product, the observer might control the consistency of his rating by reading the range of the time values of the points distributed on the line $Ve = 100$, and by then checking on range variations.

CONCLUSION

There are many questions still to be answered about this method. For example, how many ratings are necessary?[6] Is the difference between the mean standard time ($\bar{S}$) and the corrected standard (S^*), a merely formal difference, in view of the presence of sufficiently large uniformly biased errors? etc. (This last question is equivalent to asking if this method is worth applying under the present circumstances. The correct answer probably is to say that unless the rater is sufficiently trained, this method is a useless refinement.)

More answers are missing in what concerns time study rating in general. Some of these answers, however, might be provided by a wider use of the Operations Research type of approach. We have a complex system to study and improve. It is formed by observers, workers, management, machines, etc. Its output is the standard. Mathematical models have scarcely been used as yet.

[6] Until further research provides something better, maybe the answer is to plot the cumulative averages of the S_i, until the variations introduced by further values can be neglected.

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Cross Referencing Industrial Engineering Projects

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IN COMMON with most companies who have Industrial Engineering departments in several locations, we had a problem in communications. With Industrial Engineering departments in sixteen geographically dispersed locations throughout the United States and Canada, how could we keep each Industrial Engineering superintendent currently informed of projects analyzed at other locations which were pertinent to his activities? And how could we easily check back through past projects—completed at a rate of about 800 per year—to determine whether information or solutions previously developed would be applicable to today's problems?

BACKGROUND

The answers were important to us. As our production facilities are dispersed for shipping economics, most of our operations are duplicated at a number of locations. "Kleenex" facial tissue converting is carried on at five United States and four Canadian locations ranging from New Milford, Connecticut, to Fullerton, California, and from Memphis to Winnipeg. Newsprint is produced in Alabama and at Kapuskasing in northern Ontario. Printing and writing papers are made in New York, Ohio, Michigan, and Wisconsin.

Because of this similarity of production processes and also because of our nationwide distribution of finished product, we found that similar problems frequently arose at about the same time. This was particularly true of methods changes necessitated by product changes.

We were aware that there were occasions where methods, standards, and data developed by one mill could be used by Industrial Engineers at other locations—but the other mills, not knowing of this available information, would duplicate much of the previous project effort. We were solving the same problem two or three times. This did not lead to best utilization of available Industrial Engineering manpower.

Rather than starting from scratch in developing, for

example, a method for producing a changed product, it is better to start from the previously developed solution of another mill and build upon that. We did not wish to duplicate Industrial Engineering effort to arrive at the same answers to a problem; instead, any duplication of effort should be used to improve the first mill's solution.

And we knew that if a mill could receive current information on Industrial Engineering developments at other locations, this information would provide an incentive to at least match and, if possible, improve the work previously done at the other locations. We wished to stimulate competition between the various Industrial Engineering departments.

Industrial Engineering in our corporation is not the only function with a problem similar to the one described. It is a problem common to Industrial Engineering in other multi-plant corporations as well as to other professions and functions operating in a decentralized environment. So a solution while initially benefiting us, would also be of use to others.

This environment convinced us that a simple, a current, and an economical project reference system would reduce duplication of Industrial Engineering effort. Based on an idea from one of the mills, applying Industrial Engineering principles to an Industrial Engineering problem, and with suggestions from all our Industrial Engineers, we developed a satisfactory method of accomplishing this.

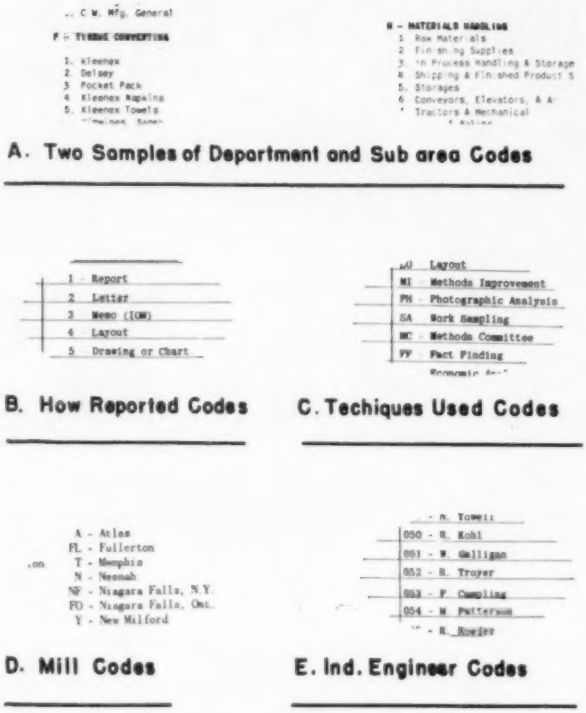

Fig. 2. Samples of Card Punching Codes.

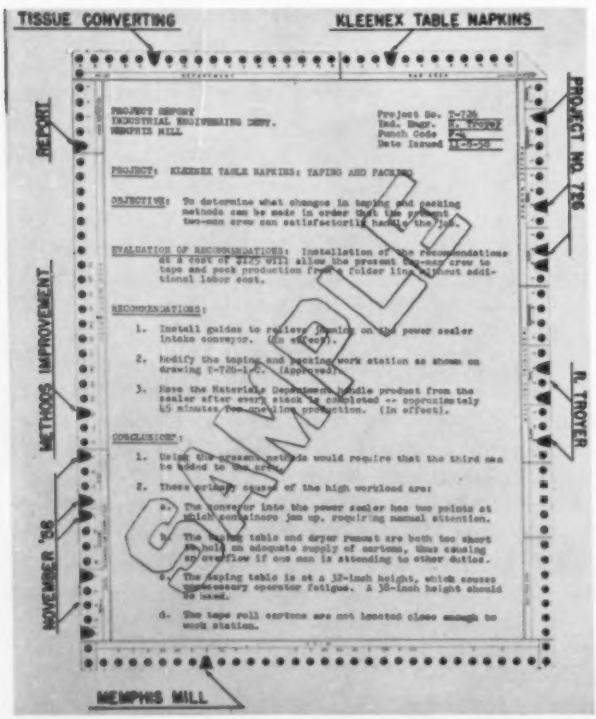
TISSUE CONVERTING
KLEENEX TABLE NAPKINS
REPORT
METHODS IMPROVEMENT
NOVEMBER '58
PROJECT NO. 726
R. TROYER
MEMPHIS MILL
PROJECT REPORT
INDUSTRIAL ENGINEERING DEPT.
MEMPHIS MILL
Project No. 7-726
Ind. Engr. R. TROYER
Punch Code
Date Issued
PROJECT: KLEENEX TABLE NAPKINS: TAPING AND PACKING
OBJECTIVE: To determine what changes in taping and packing methods can be made in order that the present two-man crew can satisfactorily handle the job.
EVALUATION OF RECOMMENDATIONS: Installation of the recommendations at a cost of $125 will allow the present two-man crew to tape and pack production from a folder line without additional labor cost.
RECOMMENDATIONS:
1. Install guides to relieve jamming on the power sealer intake conveyor. (In effect).
2. Modify the taping and packing work station as shown on drawing T-726-1-C. (Approved).
3. Have the Materials Department handle product from the sealer after every stack is completed -- approximately 45 minutes, for one-line production. (In effect).
CONCLUSIONS:
1. Using the present methods would require that the third man be added to the crew.
2. These primary causes of the high workload are:
a. The conveyor into the power sealer has two points at which containers jam up, requiring manual attention.
b. The taping table and dryer runout are both too short to hold an adequate supply of cartons, thus causing an overflow if one man is attending to other duties.
c. The taping table is at a 32-inch height, which causes unnecessary operator fatigue. A 38-inch height should be used.
d. The tape roll cartons are not located close enough to work station.
SAMPLE

Fig. 1. Typical Completed McBee Card.

PROCEDURE

As a project report is completed, it is reproduced ("Ditto" process) and copies distributed within the mill to those individuals concerned. We tacked our cross reference system onto this.

Several 8" × 10½" "McBee" cards are prepared from the report master; the exact number varies depending upon the locations which have use for a report about a particular process. On each "McBee" card, the first two pages of the report are reproduced. The holes around the edge of the card are then punched. This codes the card for: project number, Industrial Engineer, mill, date completed, technique used, how reported and, most importantly, for department and sub-area (process) studied. A typical punched card is shown in Figure 1. Figure 2 illustrates the type of punch coding used.

The punched and coded cards are then distributed to Industrial Engineering superintendents at other locations. A simple mill versus department chart determines which mills require copies of a specific card.

Approximately 40% of our projects are closed out by instruments other than a report. When a letter or memo is used, the cross reference procedure is the same as for a report. For projects closed out by a layout, a sketch, a 3-D model, or film, or by any method that cannot be easily reproduced, a short paragraph which describes the project is typed or pencilled onto the required number of "McBee" cards.

UTILIZATION

As cards are received, the Industrial Engineering superintendent reviews each for current value and application at his own location. Then the cards are filed for further reference. As the "McBee" punching readily permits cards to be needle-sorted in several ways, it is not necessary to use an elaborate filing system. At most locations all cards are just put in one file drawer; sometimes a separator is used to segregate them by year. The file drawer space used for the cards received is not great. A mill may receive 200-400 cards per year; 400 cards occupy about 5 inches in a file.

Before an Industrial Engineer undertakes a project, he reviews previously analyzed projects which may be of value to him. To do so, he needle-sorts the cards by department and sub-area; e.g. F-4 Kleenex Table Napkin Converting; N-1 for Raw Materials Handling. A quick review of the cards that drop out during the sorting determines those previous studies which are applicable to the problem at hand.

The punched cards are also used by the superintendents and by the Chief Industrial Engineer to administer and audit a department's performance. Using needle-sorting to categorize a group of cards, a summary of activity during a past period can be made. Tallying by department and sub-area indicates where Industrial Engineering effort is being expended; by techniques used indicates the types of projects being analyzed. Of particular interest are the trends of these classifications over several time periods. A review of the cards of a specific Industrial Engineer can be used for a quick review of his experience and capabilities.

REPORT FORMAT

During the development of our cross referencing procedure, we found it necessary to modify our project report format. We wanted to get as much information as possible onto the first two pages of the report. The format developed was:

IDENTIFYING INFORMATION: Mill, Project Number, Industrial Engineer, Punch Code, and Date Issued.

PROJECT: The title.

OBJECTIVE: The goal of the project analysis.

EVALUATION OF RECOMMENDATIONS: A one or two-sentence evaluation of the impact of installation of the recommendations upon operations and costs, and the estimated expenditure required for installation.

RECOMMENDATIONS: A list of actions that should be taken; after each recommendation is its status at the time the report was written.

CONCLUSIONS: A list of the facts and data developed in the course of project analysis.

DISCUSSION: Any comments which are of value in further explaining the project or which will aid the requestor in making his decision.

PERTINENT FACTS: A listing of information, data, and conditions relative to the project.

REASON FOR PROJECT: Why the project was done; what circumstances caused the requestor to ask for analysis.

REQUESTED BY: The name and position of the individual who requested the analysis.

SCOPE AND APPROACH: A summary of the procedures followed and the techniques used for analysis.

SIGNATURE: Of the Industrial Engineer who did the analysis.

ATTACHMENTS: Charts, tables, sketches, layout drawings, detailed data.

In making this modification, we found that we had made reports more readable; the most important information—the "meat" of the matter—is contained on the first page or two. It was not our intention to develop a report format that would eliminate personal discussion between the requestor and the Industrial Engineer about the project; on the contrary, we believe that a clear, concise, readable report is a valuable aid and supplement to these discussions.

COST

This system is economical in use. Initially, we spent approximately $10 at each location for a punch and sorting needle. The extra time spent reproducing, punching, and handling cards plus the cost of cards and stamps runs about $35 per Industrial Engineer per year.

SUMMARY

We have described an economical procedure for cross referencing reports from several mill locations. This procedure is used for current dissemination of project information, for reviewing past projects for pertinent information, and for administration of Industrial Engineering activities. It is workable; we have been using it for over two years and have found it satisfactory. Several other functions in our corporation have adopted or are considering the use of a similar procedure for their own use. It helps us provide more effective Industrial Engineering service to our management by using Industrial Engineering manpower more effectively.

Industrial Engineer

. . . for variety of duties in PHILADELPHIA or WASHINGTON, D.C. area plants of SEALTEST FOODS. Will do cost reduction studies, time standards development, economic evaluation of methods and equipment. Very good long range advancement possibilities into general management with this major national concern.

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What Profit It a Man?*

by **LEROY O. GILLETTE**

Chief Industrial Engineer, Felt Base and Inspection Services, Armstrong Cork Company

IF THIS were a sermon—which it is not—I could start by saying, "Brethren, my text for today is a verse from the Book of Common Sense, which reads: 'and what profit it a man if he should gain the whole world—of knowledge—and not be able to use it?' "

The purpose of this discussion is to help us find and use new tools of Industrial Engineering; or to help us understand new applications of old tools. We hope to discuss many of the vast number of techniques which have been, are being, or can be, used in Industrial Engineering. But what profit it us to have all these tools, and all this world of knowledge at our disposal, if we are not able to use them?

This may sound like a rather useless question. Yet I have read about, and listened to speeches about, many techniques which *I* cannot use. I am sure all of you can say the same.

Some of you may have heard the story about the young man from Philadelphia who wanted to be an actor, and in preparation for an intended career had studied books and had attended classes on acting, elocution and interpretation, and the like. When he felt that he knew all about acting, he hired an agent to get him a job. Some days later, he received a phone call from the agent, who asked: "Are you available?"

"Yes, I'm available."

"Well, there's a small part open in New York, if you can get up there in time for today's matinee."

"Today," said our would-be actor. "I can make it, but how will I learn the part?"

"Oh, don't worry about that; all you have to do is rush out on the stage and say: 'Hark! I heard a cannon!' Think you can remember that?"

"Sure." So our actor packed his toothbrush, grabbed a train to New York City, caught a cab, and skidded up to the theatre in the nick of time. All during the trip he had rehearsed his line: "Hark, I heard a cannon!"

Waiting at the stage door was the producer, obviously concerned by the actor's late arrival. "Are you the new actor?"

"Yes sir."

"Fine—do you know the line?"

"Sure; it's 'Hark, I heard a cannon!' "

"Good. There's your cue now; go on out there."

So our hero rushed out on the stage. Just as he reached the center of the stage, there was a terrifically loud noise from behind the scenery. *"Boom!"*

Our friend stopped and exclaimed, "What the heck was that?"

I think this is a story we all appreciate, because it hits close to home. Each of us has at one time or another had a similar experience. Having read about, or heard about, a particular situation, we feel qualified to cope with it. Yet, so startled are we by its actual occurrence, that we miss our opportunity. What profit it us to have a whole world of knowledge—and not be able to use it?

We may have philosophers who believe that knowledge for the sake of knowledge is worthwhile. Perhaps; but when we learn that boiling water is hot, we use that knowledge to keep from getting burned, or to cook hot dogs or eggs. The main purpose of *any* learning is application—use.

Assuming that we agree on this principle, I'd like to discuss for a few minutes action we can take which will help us to apply in our work knowledge that we gain here, or elsewhere. To use this knowledge, we must have practice, initiative, salesmanship, the confidence of others, a sense of balance, patience, and faith in our profession.

PRACTICE

The story about the actor emphasizes point number one: Practice is of paramount importance. The practice I speak of is not a purely manipulative affair, such as tieing a necktie, but is the thoughtful application of a planned procedure, with intent to gain understanding and confidence. This type of practice will fix procedures firmly in our minds, ready for use next week or next year.

Practice of value can only be performed on-the-job. To achieve its purpose, the practicing must be done very soon after the preliminary steps in learning have taken place; that is, very soon after the article or book has been read, or the speech has been heard, or the demonstration observed. These facts are seldom compatible with economy of time; for rare indeed is the occasion when a new technique appears at just the right time to solve a current problem. In fact, all too often current problems are of such pressing nature that we hesitate to try a new method of solution; preferring instead to use an old method we are sure of, even though the new method is expected to give more precise solutions, more quickly—after we have had a little practice.

In this respect, we are very much like the man in the plant who hesitates to use a new method. He is *confident*

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*Based upon a presentation to the Northeast Regional Conference, AIIE, November 5, 1959.

of the old method; it has enabled him to produce good material and to earn, perhaps, a good bonus.

How, then, do we get the practice we need to really learn a new Industrial Engineering technique? We must *hunt* for a potential area of application, and try the method—with or without much chance of profitable return for our time. The expenditure for a few man hours while the idea is new may prepare us to save many man hours on future problems, or to solve problems which might otherwise be beyond our capabilities.

So much for practice; except that I believe we should always budget a portion of our time for trying out techniques we as individuals have not tried before, or which are not a part of our usual routine. We should particularly encourage our young engineers to grow professionally in this way.

INITIATIVE

The second point I'd like to make is that *we* must take the initiative. We cannot expect the boss to come to us and say, "Joe, old boy, why don't you try a little Mathematical Programming on that Inspection Department project?" There are two reasons for this: In the first place, the boss may never have heard of Mathematical Programming. If he is a superintendent or a manager, he has worries on his mind which preclude his taking the time to keep up with the multitude of tools used by the chemists, the engineers, the accountants, etc. He expects each staff department to keep up on these things for him, and to recommend techniques to him, if necessary. Even more likely, he expects a solution to a problem or improvement in existing procedures, and leaves the selection of technique to the staff concerned.

In the second place, selection of the best tool to use usually must follow a preliminary study. The person best qualified to select the tool which fits the job should be the well-trained Industrial Engineer who makes the preliminary study.

So don't wait for the boss to tell you to use new tools. Likewise, he will never tell you to join a professional society, or ask if you read your professional journals, or demand that you become registered. These are matters for individual initiative. The boss wants what he is paying for—Industrial Engineering service. It is up to us to see that the service is the newest and the best available.

Real initiative requires not only that we be ready to learn and to use new techniques, but also that we seek new areas in which we can be of service. Many Industrial Engineering Departments were born as time study departments and too many of them are still considered merely time study departments— or perhaps time study and methods, or time study and standards departments. In our study of new techniques, we may recognize applications outside the traditional areas of Industrial Engineering activity in our respective companies. If so, we must have the initiative and the courage to offer service which may not be expected and which may occasionally cause a degree of resentment in the staff or production area affected by our recommendations.

SALESMANSHIP

After practice and initiative, the third thing we need in order to apply this world of knowledge is salesmanship. A lot has been written and much has been said about the "selling" of proposals to management, supervision, and production employees. The need for a good selling job cannot be over emphasized; and entire conferences have been devoted to this vital factor in the successful completion of a job. All I plan to say today is this: We can do the best engineering job it is possible to do; but unless the resulting recommendations are "bought" by the people who must appropriate the money or make the decision; unless the willing cooperation has been earned of the staff and supervisory people who must make the recommendations work; unless we at least dispel the antagonism of people affected, we may as well hang up our watches, slide rules, and 3-sigma limits. The job must be sold before it can be installed.

CONFIDENCE OF MANAGEMENT

The selling effort required can be reduced considerably if management and supervision have confidence in our ability and in our judgment. The amount of confidence placed in us depends on more than our degrees or our Industrial Engineering experience. It depends, for one thing, on how much our proposals show evidence of thorough planning and sound thinking. I once had a neighbor who was a whiz at using tools. He was a real do-it-yourself man with carpenters' tools, bricklayers' tools, mechanics' tools; and he could do a pretty good job with any of them. Every once in a while he would get an urge to build something, and in almost no time he would have the job finished. One summer he built onto his home a garage which he never used, because it was situated in such a way that it was almost impossible to get a car in and out of it. After three years, he tore it down and used the floor for a patio. This is the sort of job we must avoid if we are to have confidence of management. We can be whizzes at using our engineering tools, but evidence of half-hearted planning and half-baked proposals will get us nowhere.

Another factor which can affect the confidence management has in us is our sense of balance. A wheel which is out of balance makes driving a car extremely difficult; and a staff service out of balance makes steering a business just as difficult. Industrial Engineering has a substantial and important role on the management team. However, success or failure will depend on the effectiveness of the team as a team. Our recommendations must fit in with overall objectives, even if we must compromise between the ideal solution and the practical solution. Too often managers must choose between con-

flicting viewpoints—staff with production, or one staff with another. If we attempt to view all sides of a problem and to present balanced proposals, management and supervision are more apt to have confidence in our recommendations.

PATIENCE

So far, we have talked about practice, initiative, salesmanship, and gaining the confidence of management. The next requirement, if we are to use these tools of Industrial Engineering, is patience.

Everything that we accomplish is done by people, and likewise everything that we do affects people. Changes that affect people *can* be made rapidly, but seldom are. Accomplishing results with these tools of ours might require a series of small steps instead of one big jump. We may have to wait years for just the right time or for a change of personnel. Impatience will accomplish little except to cause frustration. Most of us have had the experience of turning up the blade of a plane a little too far, in order to hurry up a planing job. You know what happens—we either "botch up" the whole job, or gouge it so deeply it takes a lot of work to smooth things over. It may take longer, but a job accomplished with sandpaper is a lot smoother than one done with an axe. I've heard it called "erosion rate" and "absorption rate"; whatever we call it, each group of persons with whom we work has a maximum rate for accepting change. Speeds in excess of this rate are sure to be hazardous. We must learn to judge how fast we can move, in order to accomplish as much as possible without bringing our entire program to a crashing halt.

CONCLUSION

One final point: We must be sure we are doing the right thing. I think Industrial Engineering is almost a way of life. When I was about eight or nine years old, my dad used to buy canned milk and other canned goods by the case. Every once in awhile one of the neighbors would run short of something, and would buy a can from us to save a trip to the store. One lady in particular came over often to get milk. The canned goods was kept in the cellar, and mother usually sent me down for a can. Well, one summer this neighbor came over every day, several days in a row, asking for a can of milk each time. I became a little tired of running down to the cellar every day, so on one occasion I brought up a whole armload of milk cans. "Here Mrs. S.," I said, "Take several so that you won't have to come back so often."

Mom called it being fresh! I think it was the awakening of interest in Industrial Engineering. Whether the tools we use are new or old, we are trying to accomplish certain objectives: payment for work in proportion to value of the service rendered, cost reduction, higher productivity, more efficient utilization of the factors available, better methods. These objectives become a part of us; why, I even have an Industrial Engineering haircut! At least, having it cut short this way saves me an estimated $8.28 per year on hair tonic (plus 36¢ tax); saves a little over 18 man-hours per year I used to spend combing it; and enables me to have my hair cut in about four minutes flat!

At times the product we have to sell is unpopular. A foreman knows that a crew reduction causes grumbling and resentment, and may require more attention on his part in the future; an office manager fears that our studies may mean he will lose a clerk; an incentive installation may mean less time for pinochle. These are not projects calculated to win friends and influence people. And yet, I am sure that each one of us is convinced that these constant changes are necessary in order to keep our respective organizations competitive; that in a world crying for good things of life that can be supplied by our companies, there is no place for wasted effort or restricted output; that in a nation plagued by spiraling costs and prices, there is no sense in permitting inefficient methods, featherbedding, and the like to add unnecessary increments to our costs—increments which are bound to price the product beyond the reach of some potential customers. These are beliefs we share, or we would not be Industrial Engineers. We must be sure that our work is for the ultimate good of our employers and our fellow men. Otherwise we shall not have the courage and stamina to use this world of knowledge effectively.

In our profession, you and I, as individuals, must rely on *ourselves* for the efficient, successful practice of our profession. Every step in the process of applying the knowledge we gain depends primarily upon *our* taking action. *We* must practice new techniques to make them a part of our personal knowhow; we must take the initiative in the use of the best techniques available for accomplishing a given task, whether they be old techniques or brand new ones; and the initiative in applying our skills in as many areas as show the need for service we can render; *we* must sell our proposals before they will be accepted; *we* must so conduct ourselves professionally as to earn the confidence of the people with whom we work; *we* must be patient in seeking the accomplishment of our recommendations; and *we* must have faith in the need for the work that we do.

If we do all these things, we need not ask what it profits us to have a whole world of knowledge, for we shall be using that knowledge to profit ourselves, our employers, our fellow workers, and the consumer—who are, of course, all mankind.

Work Measurement In the Post Office

by **G. B. BAILEY**

Vice President
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New York

EARLY in 1957 the United States Post Office Department started to install time standards in five post office centers. Before the end of 1957 installation work at these offices was completed and work was started in six more offices. The program continued to expand. By the end of 1959 standards were in use in over 65 post offices stretching from Miami to Seattle. New offices are added to the program at the rate of 20 to 25 a year.

The number of people, on mail handling work at an individual office, varies from 50 to 2,000. The average number is about 300. The standards are used in two ways:

1. To plan total staff requirements.
2. To assign staff to the different jobs.

The result is better use of staff and improvement in output per man-hour. The average rate of improvement from the use of standards is shown in Figure 1.

PILOT INSTALLATION

The program began with a pilot installation at Fort Worth, Texas. Standards were set by means of Basic Motion Timestudy and applied to all of the main mail handling operations.

As soon as standards were in use at Fort Worth, members of the Office of Research and Engineering, who direct the program, prepared to extend the program to post office centers across the nation. They summarized the BMT studies that had been made and used this information to develop standard time data and time formulas. Then they compiled a manual that tells how to use the standard data and time formulas to set standards for the main mail handling operations in any post office.

Length of Time that Standards Have Been in Use	*Rate of Improvement Since Standards Have Been in Use*
1 year	20%
1½ years	30%
More than 2 years	35%

FIG. 1. Improvement in Rate of Output Resulting from the Use of Time Standards.

TRAINING PROGRAM

When this preparatory work was finished, the Research and Engineering people began to select and train staff to be used to extend the program. The training methods chosen are still in use. New staff is trained in groups of about 15. Each group is given four weeks of concentrated classroom instruction in the work measurement techniques that are used as well as instruction in how to use the manual of time data. Then the trainees return to their home offices to work under full-time direction for two to three months as required while standards are set and put into use.

Each group of trainees is made up of representatives from five to ten post offices and from one or more of the fifteen regional offices in the country. Regional staff, after training, provide field supervision and otherwise lighten the administrative load that members of the Office of Research and Engineering had to carry at the beginning.

So far only 135 work measurement engineers and technicians have been used to set standards and keep them up to date. Of this group, approximately 100 are assigned full-time to post offices. The others are supervisors who work either from one of the regional offices or from Washington.

These figures work out to an average staff size of about two people per post office. Even so, the program moves forward at the rate of almost two new offices per month.

The program has advanced at a rapid pace because of the careful preparations that were made at Fort Worth. The standard data and time formulas that were developed from the Fort Worth BMT studies have proven to be well put together. They have been widely used without major change. So far only two additions have been needed to supplement the original data. One covers an operation that was too small to study at Fort Worth. It is a major operation only at large centers. The other covers a new method of sorting mail—a method that had not been developed when the Fort Worth study was made.

EXPLANATION OF SORTING

The ease with which the time data can be used to set standards at new post offices is likely to be misleading. It suggests that the method of sorting letters (and therefore the time to sort one letter) is the same in every office. This notion may be strengthened when you recall how mail is sorted.

A mail sorter stands in front of a large box that is cut up by thin partitions into a number of small pigeonholes. In post office language the box is a case; the pigeonholes are separations. Each separation is at least as wide as a letter and high enough to hold 50 to 60 letters. The sorter holds a dozen or more letters in his left hand with the addresses all facing up. He reads the address shown on the top letter; he carries the letter with his right hand to the separation that corresponds to the address on the let-

ter; he deposits the letter there and returns to repeat the process with the next letter.

If you spend some time watching a sorter at work in one department then move on to watch another sorter at work in another department or in another office, you will soon see differences of which you were not aware. You will see that the sorting cases are not all the same size. Some are wider and taller than others. This means that the average distance that the sorter has to carry a letter to deposit it in a separation will not always be the same. Actually the distance varies enough between a large case and a small one to affect the time per letter by more than 10%.

Then you will notice that the separations are not all the same size. Some are only slightly wider than a letter. Others are two or three times as wide as a letter. The large separations are located at the center of the case. The mail sorter is able to carry a letter directly to one of the large separations with the merest glance toward it. In fact, very often he does not even look at it. By comparison, he has to look at each small separation. He also has to use more deliberate motions to dispose of a letter to a small separation. Differences in the proportion of small to large separations in a case can affect the time per letter by as much as 10%.

As you watch the sorter you will also see that some separations receive more letters than others. As you would expect, the large separations at the center of the case get far more letters than the small outside separations. This distribution of letters affects the average distance the mail sorter has to reach to carry a letter to its proper separation. The more letters that go to the separations at the center of the case, the shorter the distance the average letter is carried. The proportion of mail that goes to each separation is likely to vary from one office to another. Therefore, the weighted average distance has to be calculated for each new office.

To take into account variations of this sort, a series of time formulas was developed. For example, one formula was designed to deal with the distance that the clerk has to move his arm to carry a letter to the separation and to return. It is expressed in the following form:

Net Standard Time per Letter: $5D + 126$
(in .0001 minute)
where D = the distance from the center line of the case to the nearest edge of the separation to which the letter is to be deposited.

The value for D is found by taking a weighted average of the distances moved to dispose of letters in a sample of proper size.

If you watch the letter sorter carefully, you will see that his right hand often pauses after it grasps the top letter in his left hand. When this pause occurs it means that the sorter has not had time to read the address on the envelope to learn into which separation the letter is to go. That is, the hand work to carry a letter to the separation, dispose of it and return has taken less time than the reading work that goes on at the same time.

As implied, the right hand does not always pause; the reading work does not always take longer. We have already noted that the hand work changes because of changes in the size of the case, the size of the separations and the like. Reading work also changes for reasons that may be defined.

When a clerk sorts mail that is to be delivered to addresses in the city, he looks at the destination—the street address—rather than at the name on the letter. But there is more to it. He only reads enough of the address to tell him where to put the letter. If, for example, he sees the address 1070 Bay Street, he may only identify Bay before he knows where to put the letter. This will be so if:

1. There is no Bay Avenue, Crescent, Boulevard, etc. in the city.
2. There is no North or South part of Bay Street.
3. There is no division of Bay Street into postal zones.

If there is also a Bay Avenue in the city, he will need to read on to learn that this is Bay Street. If Bay Street divides at 1000 between two postal zones (or two mail carriers) he will need to read the number 1070 as well. 1070 Bay Street takes more than four times as long to read as Bay.

There is another factor that bears on the amount that the mail sorter reads. He may find a street called Glenview. If there is also a Glengrove street and a Glencairn street in the city, he will need to read the entire two syllable word Glenview to make certain that he knows where to put the letter. If, however, there is no other street name of more than one syllable that starts with "Glen," he will only need to read "Glen" to know that the rest of the word is "view." It takes almost 20% longer to read Glenview than to read Glen. The difference is even greater when the full street name contains more than two syllables.

Reading time data need to take these factors into account. When ready for use, the data should provide for time to read and understand what is read. There is only one way to find out how long it takes to read and digest the information read so that action can be taken. That way is to actually time it. This is no problem. A number of addresses with one syllable street names can be arranged for timing. An operator can be timed as he reads these addresses and determines from what he has read the separation to which each address is to go. The result gives the actual time required to read an address made up of a one syllable word.

Other tests can be made for addresses of two syllable words, three syllable words and so on, with and without street numbers of different size.

When all the tests are finished, there will be at hand actual times for reading and digesting addresses made up of any combination of word size and number size that is likely to be met. However, the tests will not tell whether the operator read fast or slow—whether he read at stand-

ard pace, faster than standard or slower than standard. This information is needed. The time for the hand work is set for standard pace. The time for the reading work must also be set for standard pace.

READING TIME

The method used to evaluate eye pace was described in the November-December 1958 issue of the *Journal of Industrial Engineering*. Briefly, it makes use of bench mark reading tests for which standards have been set in much the same way that the walking standard of three miles per hour and the card dealing standard of .50 minute were set for hand work. To develop a reading time standard, an operator reads the bench mark test, recording the exact time for reading it on a watch. He then reads the material for which a standard is to be set (in this case, a number of addresses), to the best of his ability using the same reading pace. He also records on a watch, the exact time for reading the addresses. Several trials are made, some at moderate pace, some at relatively slow pace and some at relatively fast pace. Standard time is found by the following calculation:

$$\text{Net Standard Reading Time} = \frac{\text{Bench mark standard time}}{\text{Bench mark actual time}} \times \text{Actual reading time for one address}$$

From a series of tests such as those mentioned, time data were developed for reading addresses of various size. These data may be set out in tables or expressed as formulas in the following manner:

Net Standard Reading Time:

1. Per address $= 41W + 8S + 66$
   Where W = number of words in address
   S = number of syllables in address
2. Per street number $= 32N + 33D$
   Where N = number of numerals in address
   D = number of digits in address

Reading time data set out in this form (or in tables that show the same information) are flexible. They can be used to set reading time values quickly for any address. The reading work can be compared with the hand work (to dispose of a letter) that goes on at the same time. When more time is needed to read than to do the hand work, the job standard is based on the reading time. When more time is needed for the hand work the standard is based on it.

The formulas already mentioned are used in Figure 2 to show how to set a standard for the following specifications:

Distance to separation	= 5 inches
Words read per address	= 1
Syllables read per address	= 2
Numerals read per address	= 1
Digits read per address	= 4

Reading Work		*Hand Work*
1. *For words*		
$41W+8S+66$		$5D+126$
By substitution		By substitution
$(41\times1)+(8\times2)+66=123$		$(5\times5)+126=151$
2. *For street numbers*		
$32N+33D$		
By substitution		
$(32\times1)+(33\times4)$	164	
Total	=287	151

Net standard time per letter, based on reading work
=287 BMT units or .0287 minute.

FIG. 2. Standards for Reading Work and Hand Work are Calculated Separately. In this Example, Net Standard Time per Letter is the Time For Reading Since the Hand Work Takes Less Time.

STANDARDS

These procedures make it easy to set proper standards quickly at any post office. As mentioned earlier, this is the main reason why standards have been set in so many offices in such a short time.

In the Post Office Department, the method of allowing for the reading work that the mail sorter has to do has always been regarded as a key part of any procedure for setting standards. There is strong feeling that more is involved in reading the address than an outsider realizes. The mail sorter has to read the address and then remember where the address goes in the sorting case. There is some "think time" for every address. Time standards for reading need to take into account both reading time and think time.

It is reassuring to the Department to know that the method used to set reading time standards allows for think time. The Department knows that the allowance is made in the only way it is possible to do so—by actually timing the operation. The operator reads an address, pauses (if necessary) to remember where it goes before moving on to the next address. The watch records the time to read and understand what has been read.

The Department also knows that the method of converting actual reading time to standard reading time, referred to earlier, is important. Until they are adjusted for pace, actual times for reading are no better for setting standards than actual times for hand work.

In the Post Office Department, staff members are not asked to accept the pace rating method that is used to set reading standards without evidence that it produces acceptable answers. During classroom training, each trainee, is taken through the rating procedure in three steps.

In step one each trainee is given a test to read. He is asked to time himself as he reads in turn at slow, medium and fast pace. At this point we want each trainee to see that he can, by design, read fast or slow.

In step two we give him a second test sheet and ask him to read the two test sheets at the same pace. He reads one, recording the time for it. Without pause he reads the other at the same reading pace, recording the time for it

also. We plot the results for each trainee on a graph. He sees that when he reads one test sheet at a slow pace, he reads the other at a similar slow pace; when he increases his pace on one, he increases his pace on the other in the same proportion.

In step three each trainee sets a standard for a third test sheet using as a bench mark a test for which a standard is already known. By this time, each trainee knows how to use the rating procedure although he is short on experience. He has only used it for a few hours. Even so, the standards set by the trainees are always in close agreement.

As an added bit of interest, we tell the trainees in advance that this will happen—that their standards will be in close agreement. We also tell them in advance that the standard they set will be in close agreement with the standards set by previous groups who have gone through the same procedure. Later we show them that all this has happened as predicted.

CONCLUSION

In a way it would be nice to close by saying that by these steps, staff members who were hostile to the standards program made a complete about face. At least, it would be impressive. However, the facts are impressive enough. No one who is close to the program has even been hostile. Each person could see the benefits that would be obtained from the use of a well designed and carefully administered standards program. However, many of them had to be convinced that the work measurement techniques being used would produce proper standards.

One objective of classroom training procedures has been to gain confidence in the work measurement techniques. Taking part in reading tests as just described is one way this objective is met. The other way is to show that the BMT standards for manual work are reasonable. In classroom training, BMT standards are set for a number of jobs. After the standard is set, each job is demonstrated and timed at different levels of pace. The trainees (few of whom have had experience in work measurement) are thus able to see that standard pace is reasonable.

The time that has been devoted to this form of training has been worthwhile. Each staff member supports the techniques used to set standards for both the hand work and the reading work. His support is reflected in his work.

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A Research Approach in Management Controls[1]

by **ALAN J. ROWE**

Manager, Business Management Control Systems Research, System Development Corporation

AN IMPORTANT challenge awaits the business manager of the future. In spite of expert advice on business operations and the availability of computers, management decision making and control are still extremely difficult and complex tasks; and with the inevitable shift from emphasis on intuition and judgment to management skills, the role of managers will become increasingly important.

To conduct research in management controls, however, a number of formidable obstacles must be overcome. Unlike engineering or the physical sciences, there are no convenient laboratories for testing new ideas and methods. Experimentation directly in an actual plant presents numerous difficulties; and the introduction of repeated changes in an existing system would cause resentment as well as unreliable results. System modification, repetition, or control of experiments may be virtually impossible in real-life situations. The required time and cost of testing new methods is often prohibitive. Computer simulation, on the other hand, provides an effective and rapid means for examining complex system problems, since the computer is capable of examining a year of simulated activity in a matter of minutes. In addition, data on system performance can be obtained which are unavailable in actual situations. Because of the foregoing considerations, the computer appears to provide a suitable laboratory for conducting research into new management control methods and ideas.

BACKGROUND OF THE PROBLEM

Although management control is widely discussed, little has been done to formulate a body of principles for use in business system design. It is interesting to note that the system aspect of control has not been widely applied in industry. Although the servo-concept of control in management was described by Simon (9), it was only recently that the use of integrated controls or the system approach has been expounded (8). A natural extension of the systems approach is to include optimization into the design aspect of the problem. That is, a system should be "designed" to meet specific requirements before establishing controls. Based on this consideration, we can say that management control is concerned with integrated systems of men, material, facilities, and funds, to specify, predict, and assure the results desired from such systems.

An important problem related to management control is the decision making process. In carrying out their daily activities, managers are confronted with discovering possible alternate courses of action and their consequences. Ultimately, what is required is a suitable basis for choosing among these alternatives. Where problems are well-formulated, mathematical or logical decision rules can be applied which help achieve control. However, the majority of management decisions involve interdependencies among a number of activities. The joint optimization of many factors presents the complexity in solving the problem of decision making.

In addition to the difficulty of evaluating the effect of a given decision on the numerous activities within a business, there is the problem of variability of system inputs and system performance. The stochastic behavior of events is characteristic of the majority of problems in management controls and, in part, accounts for the difficulty in predicting system performance. A better understanding of the statistical aspects of system behavior will greatly aid in achieving correct design of management control systems.

RESEARCH PROBLEMS IN MANAGEMENT CONTROLS

Research in management controls should consider the behavior of the system as a whole. This research approach poses the following problems:

1. Relationship of system design to control.
2. Suboptimization as a result of component control.
3. Formalizing of system objectives.
4. Measurement of system performance.
5. Design considerations in management controls.
6. Relationship of formalized decision rules to control.

RELATIONSHIP OF SYSTEM DESIGN TO CONTROL

An important consideration in establishing management controls is to relate system requirements to the control methodology. Thus, research in the development of improved controls will be based on the assumption that system design precedes design of management controls. However, the design of complex systems to meet specified requirements often requires experimentation. Where an actual system exists, it could be used as the basis for

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modelling in order to conduct simulation experiments. However, as is often the case, when a new system is being designed it has an entirely different set of requirements than existing systems. The model in this latter case must, of necessity, be based on experience and judgment rather than a real life counterpart. Research, in many respects, is concerned with systems which do not exist today. Therefore, a method of examining a multitude of possible systems in a test-tube-like fashion is needed. Computer simulation appears to meet this requirement.

SUBOPTIMIZATION AS A RESULT OF COMPONENT CONTROL

Optimizing components or parts of a system, may lead to suboptimization in the total system. Thus, for example, costs which are incurred in purchasing, storing processing, and shipping should be combined rather than treated separately. As another example, rather than compute order quantities without considering other factors they should be dependent upon inventory status, machining costs, scheduling requirements, financial status, marketing position, etc. (4). It is apparent that the simultaneous consideration of many factors poses a tremendous strain on any information processing system and would undoubtedly require computer assistance. However, once these interdependencies have been established, it may be possible to employ a simplified control mechanism.

FORMALIZING OBJECTIVES

Probably one of the most difficult aspects of establishing controls is the lack of formalized objectives in business. The old cliché of profit being the objective of a business enterprise is gradually disappearing (3). From the system view, there should be a number of concommitant objectives. Not all objectives are alike, however, since they are a function of the willingness of management to take action in the face of uncertainty and with inadequate information. Presumably, computers can provide information in a form useful for analysis and evaluation of a number of alternatives which can serve as the basis for establishing realistic objectives. For example, management might state as an objective an increased share of the available market for a given product. An economic analysis of the factors involved might prove this objective unrealistic. It is possible that for a given capacity, capital structure, distribution system, etc. that the costs far exceed the value gained from obtaining a greater share of the market. The difficulty in formalizing such objectives arises from the fact that there is no simple method for evaluating the impact of objectives on a complex system. Without this evaluation, the objectives may be meaningless. For this reason, simulation seems like a suitable approach to the problem of specifying "meaningful" objectives. This same argument can be extended to the design of the system itself. Alternate designs should be compared and evaluated prior to actual implementation of a system. In business systems, the computer can provide the necessary vehicle for this experimentation and evaluation.

MEASUREMENT OF SYSTEM PERFORMANCE

Measurement of system performance should be an integral part of management controls. However, conventional bases for measurement, in many instances, do not truly reflect performance nor provide control. For example, high inventory turnover may lead to stock shortages. Therefore, turnover may be an inadequate measure to insure desired system performance. The majority of present methods of measuring performance can be traced to the lack of large scale data-processing media. With increased storage capacity in computers, the processing and summarization of operating data will prove less formidable than in the past. This should permit the development of measures of performance which are based on actual operations. Control information can then be a by-product of normal transactions based on integrated data processing.

DESIGN CONSIDERATIONS IN MANAGEMENT CONTROLS

An important consideration in the design of management controls is that the controls do not become ends in themselves. Budgeting is an excellent example of the situation where funds are often spent, not because they are needed, but to prevent a cut at a later date. Costing is another example of requiring system performance to conform to arbitrary controls. Thus, the management control problem is further confounded by the fact that given properly designed systems and correctly established objectives, the controls may lead to poor system performance. This has been demonstrated by Forrester in his treatment of induced fluctuations in inventory and production as a result of poor controls (5).

A number of considerations should be taken into account in the design of management controls, such as:

1. What are the limits or deviation from standard which provide the basis for action?
2. How is the system aspect included?
3. How can decision rules be used for control?
4. Can feedback be treated as a sampled data problem?
5. What controls are sensitive to transient problems?
6. Can general principles such as the exception principle be developed?

In addition to the foregoing, management controls will depend on the system design, although there are control principles which are independent of the particular system. Optimization procedures or decision rules are also controls since they assure specified system performance.

RELATIONSHIP OF DECISION RULES TO CONTROL

Unless formalized decision rules are available, the computer merely acts in the role of a data processor. On-line computer control, in reality, implies a form of automated decision making. On the other hand, the computer can also be used to present information to managers as an aid

in decision making. The majority of decision rules developed in business to date, however, give no consideration to the system aspect of the problem. Rules for optimal safety stocks, for example, do not consider the cash position of the company at the time an order is placed. As an alternative to formalized decision rules, computer simulation can be applied in a heuristic approach to problem solving. Thus, if the cash position were low, a simulation run could be made to predict the effect of alternative solutions to the problem.

A problem in the use of decision rules for management controls is that the solution of a problem having a large number of variables is formidable. Although the outcome of a particular combination of variables is difficult to predict, the results often form a stable distribution. Thus, for example, when jobs are processed in a factory, the completion of any specific one cannot be predicted, nor the sequence in which other jobs will be completed. However, it is possible to predict the over-all distribution of job completions. This can be depicted graphically as shown in Figure 1. Thus, rather than treat this as a permutation problem, it is considered a stochastic process having a definite distribution. In a like manner, problems involving a large number of variables in management controls can be treated from the statistical viewpoint.

The use of a combination of formalized decision rules and computer simulation for management controls opens up interesting new vistas. In effect, it would be possible to have detail planning for problems which extend further out in time than is currently done. Thus, rather than daily or weekly labor forecasting it would be possible to have realistic monthly or quarterly forecasts. Conversely, the problem of annual budgeting could be handled on a more refined basis. Thus, rather than wait until year's end to find out that a budget was over or under the predicted amount, the business could respond to changes as they occurred. This of course presumes that flexibility has been designed into the system to permit rapid response to the changing environment. Research in management controls should have as one of its objectives the study of real-time problems such as these.

A RESEARCH APPROACH IN BUSINESS MANAGEMENT CONTROLS

A basic question to be answered in management controls research is the scope of the problem to be considered. The majority of control research in industry today can be classed as component or subsystem control. There is a lack of concentrated effort, from the system viewpoint, on the business as a whole. Thus, our approach is to study the entire business as a logical system.

As in any research program, the starting point should be a survey of the field to establish the state of the art. These findings should prove helpful in providing guidance in the research. In addition, a research plan should include the following:

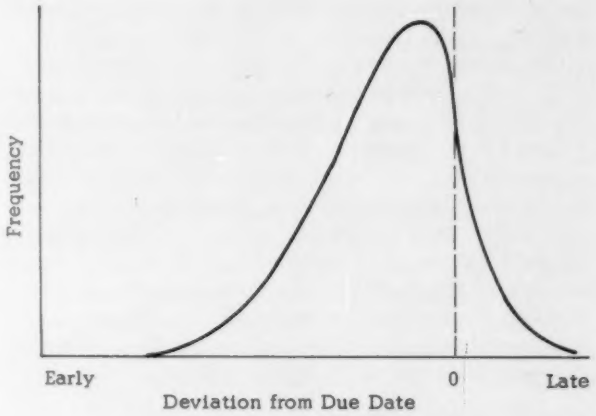

FIG. 1. Distribution of Job Completion.

1. A well formulated model of the elements, characteristics, and structure of management control systems.
2. A general purpose computer model for simultation.
3. Design of decision rules for management controls.
4. Study the behavior of the computer model to gain insight into the problem and validate experimental conclusions.

DEVELOPING A MODEL FOR MANAGEMENT CONTROLS

In order to study these problems in management controls, the programming of a general purpose simulation model appears appropriate. This model would be designed for use on a large, high speed computer and, when programmed, would provide both a research and training tool. An important factor favoring a general purpose model is that this would serve as a basis or focal point for discussions with persons concerned with management control applications. It would also permit the research to be of a broad and fundamental nature rather than the solution of specific problems.

An important characteristic which the model should have is the ability to examine the effect of changes in management controls on system performance. For example, how would a change in decision points affect information flow rates, time lags, or queueing in a given system? Similarly, how can decision rules, which provide systematic response to variable inputs, permit optimization in a system? To permit study of component interactions the program should also contain decision rules which have a conditional response based on given decision criteria.

A COMPUTER MODEL

To model the organizational structure of a business, a network of decision points, information channels, and authority relations can be used. The interactions and interdependencies of a typical business should be taken into account, as well as formalizing inputs, outputs, and system transfer functions. Objectives would be formulated in quantitative terms. The information flow, feedback loops and decision points would be used in the

model to establish the organization structure for decision making.

One means of indicating information flow or relationships among decision makers is the use of a matrix notation. Conditional decision responses can be represented by a special logical notation. These decision responses serve as transfer functions which describe the behavior of the system under varying conditions. Measures of system performance would be an integral part of the model with the computer summarizing various kinds of data. Alternate methods of summarizing these data would be useful for studying information flow and evaluation of system design. In addition, the model should be capable of handling stochastic behavior of the system elements.

DESIGN OF DECISION RULES IN MANAGEMENT CONTROLS

Quoting from Drucker's article on long-range planning, we can clearly see the need for formalized decision making in management (2).

> It is not within the decision of the entrepreneur whether he wants to make risk-taking decisions with long futurity; he makes them by definition. All that is within his power is to decide whether he wants to make them responsibly or irresponsibly, with a rational chance of effectiveness and success, or as a blind gamble against all odds. And both, because the process is essentially a rational process, and because the effectiveness of the entrepreneurial decisions depends on the understanding and voluntary efforts of others, the process will be the more responsible and the more likely to be effective, the more it is a rational, organized process based on knowledge.

Although there are many ramifications to management decision making, from the point of view of management control research, the following aspects of decision making can be considered:

1. The bases or criteria for making decisions.
2. The information required to make decisions.
3. Where decisions are made and by whom.
4. The number and type of decisions made at various organizational levels.
5. The response rate required for decisions after information is received.
6. The time taken to actually make the decisions.
7. The induced lags or delays in information flow due to decision making.
8. The noise or errors in the decision-making process.
9. The relation of organizational structure to decision making.
10. The bases for automating decisions.

Although this list is not exhaustive, it indicates the kind of problems confronting research in management controls. Behavioral and motivational characteristics of decision making will be considered, where these can be quantified or modelled.

TESTING THE MODEL

In order to have assurance that a model responds to inputs in a manner comparable to actual system behavior, it is necessary to validate the outputs. Using actual data, or suitable approximations, the results obtained by running the model should be comparable to known behavior. Following the validation, experimentation is necessary to test hypotheses on system design and decision rules. Both types of testing are difficult and require designed experiments. In view of the fact that simulation is a synthetic means of generating experimental data (often referred to as the Monte Carlo Method (1)) and that computer time is expensive, unlimited sampling would not be justified. Special sampling techniques are necessary to have assurance that a given decision function is applicable as a basis for action with a minimum expectation of risk.

The research approach, then, is to start with a well-formulated statement of the elements, characteristics, and structure of management control systems. This would serve as the input for an initial model in which only the critical variables have been included. A sensitivity analysis would be used to determine which are the important variables as well as the significant range of parameters. One method for determining which factors are important, and to assure realism, is to discuss the initial model with various business managers. The formalizing or modelling of the problem is a difficult, yet critical, task. The model should be designed for ease of modification or adaptation to suit specific variations in order to cover a wide range of research problems in management controls.

DESCRIPTION OF A GENERAL MANAGEMENT CONTROL MODEL

Many problems must be surmounted to adequately model a business system for studying management control problems. The purpose here is to explore in some detail the means whereby this modelling can be achieved. The problems discussed are not intended to be all inclusive; rather, the effort is directed toward demonstrating that many aspects of business system behavior can be formalized and stated in quantitative terms.

Starting with a simplified hypothetical organization, as an example, an approach to modelling can best be explored. Figure 2 represents some of the typical functions found in a business enterprise. Department heads *B*, *D*, *E*, and *F* report directly to the manager *A*. Purchasing *C* reports to *B* and Personnel *G* reports to Finance *F*. These are similar to conventional authority channels; however, they do not represent the dynamic interrelationship of these functions. A simulation model, on the other hand, can portray various alternate relations as a function of

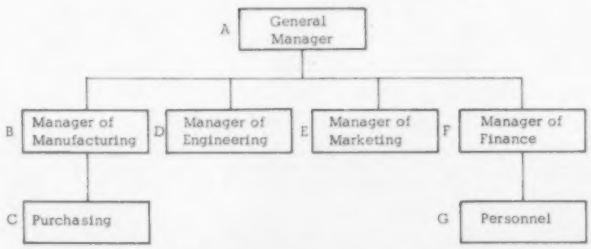

FIG. 2. Hypothetical Organization Chart.

	A	B	C	D	E	F	G
A							
B	x						
C		x		y			
D	x						
E	x						
F	x						
G						x	

FIG. 3. Organization Matrix.

time, urgency, or decision criteria. For the present, let us represent this conventional organization chart in the form of a matrix as shown in Figure 3. Thus, as was shown in Figure 2, *B*, *D*, *E*, and *F* report to *A*, and *C* reports to *B*. Note the ease of showing where all the persons report by merely placing *x*'s in the matrix and also the possibilities of modifying these relationships. Informal or secondary channels can be represented by other letters such as *y*. Thus, for example, purchasing may report informally to the engineering manager and is shown by the "*y*."

In a similar manner, matrix format can be used to indicate information flow, material flow, etc. For example, a formal information flow pattern might be as shown in Figure 4.

The numbers shown inside this matrix indicate the sequence of flow through the organization, as well as the originator of the document. The letters correspond to the organization chart in Figure 2. Special codes such as zero can be used to indicate that the document or data originated outside of the system.

The letters alongside the matrix, $D_1 \ldots D_n$, are the coding to identify specific information. This may be a telephone call, a sales report, a customer order, absenteeism report, etc. In this way, the communications network can be formalized. In addition, informal information flow can also be incorporated into the matrix.

This matrix arrangement can also be used to represent raw data or system status. Referring to the matrix in Figure 4, the manager may issue a directive D_1 to his department heads (who are all presumed to receive the communication simultaneously) and they, in turn, may be expected to take appropriate action. This directive, in effect, causes a decision to be made by each of the department heads. The basis for their decisions and the consequent actions would all be part of the computer model. Another type of information flow is shown opposite D_4. Here the general manager receives information on the market position of the company and forwards this to the marketing manager. However, the dynamics of this situation must be represented within the computer model to attain realism. For example, how soon is the information transmitted and how long is it before the marketing manager takes appropriate action. These are some typical questions which can be looked at in the simulation model.

Still another form of information is shown opposite D_5. The manager of manufacturing notifies personnel that there is a shortage in a given skill category and that hiring should proceed. The zero in the box opposite D_5 is now used to indicate that this information is a result of the system performance. Thus, as data are summarized and made available at various points they become inputs to the information flow. The kind of data, manner of summarization, and frequency of reporting would all be part of the simulation program. By providing for variation in the pattern of information flow, it should be possible to examine the effect of reporting on system performance.

THE MODEL OF DECISION MAKING

Decision making and information flow are both critical aspects of a business simulation model. For our purpose, we can conceive of the decision making process as consisting of the following elements:

1. A triggering or forcing function which initiates the decision process.
2. Decision criteria which provide the basis for response to given stimuli.
3. Decision rules which provide formalized response as a function of variable input.

Directives, Documents, Data, Information

Decision Makers

	A	B	C	D	E	F	G
D_1	1	2		2	2	2	
D_2		1		2	3	4	
D_3		1	2				
D_4	0				1		
D_5		0					1
.							
.							
.							
D_n			1				2

FIG. 4. Information Flow Matrix.

4. Action taken as a result of the decision process.
5. Outcome or result of the actions on system performance (including latent effects).
6. Feedback to correct decision criteria or decision rules.

One aspect of human behavior is the problem of predicting exact response for a given stimulus. Therefore, certain behavioral or motivational aspects of the problem can be subsumed by variability in the above elements of decision making. However, it is possible to construct formalized organizational relations which directly alter or affect the decision making process. Where these can be explicitly modelled, they would be included in the program.

It is possible to establish logical relationships which use the state of events as the basis for decisions to be made. Thus, as systems change, certain events become critical and trigger information flow to decision makers. Suppose, for example, a part completes its processing in the factory and is ready for assembly. When it reaches this state of completion, the information could be transmitted immediately to various decision points. Or, the information processing system may be such that at the end of each day Production Control is the only one notified as to which parts have been completed. They, in turn, might take certain action depending on the state of completion of mating parts. Thus, a logical comparison as a basis for decision making might be made as follows:

1. Is part A complete? Yes.
2. Is part B complete? Yes.
3. Is part C complete? No.

If the assembly requires all three parts, then the answer —yes, yes, no, would lead to a different decision than three yes's. This can be represented as follows:

1. Part A has been completed. What decision should now be made?

TABLE 1

Decisions Normally Made at this Point—Trigger Function	*Logical Considerations or Decision Criteria*	*Action to be Taken or Decision Rules*
1. Part reaches completion status.	1. Review all mating parts to be completed.	1. If all mating parts are completed, send to assembly. 2. If one or more parts have not been completed, send this part to accumulation area.
2. Request for raw material.	1. Review order point	1. If order point has been reached, check forecast usage— a. If forecast usage is the same, compute the economic order quantity and send order to purchasing. b. If usage has changed, send a request to engineering for further information.

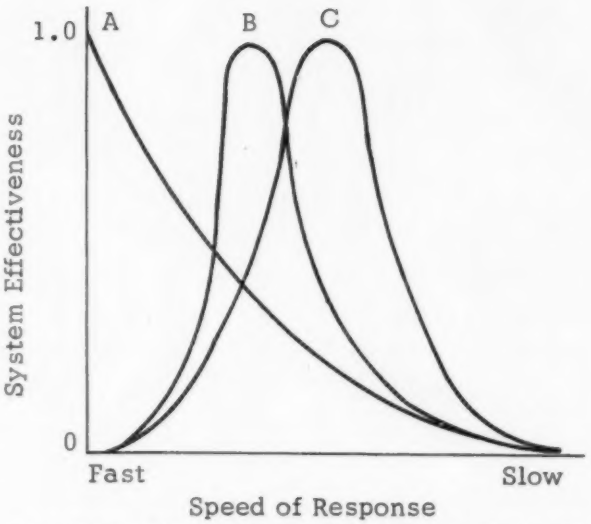

FIG. 5. Relationship of Information Flow to System Effectiveness.

2. Determine completion status of mating parts.
3. If all three are completed, proceed to assembly.
4. If any component is not completed, place parts into an accumulation area.
5. Repeat the check on status of mating parts after a suitable time interval.

The various specific decisions, or classes of decisions to be made at decision points can be represented in tabular form. In the computer model, a search would be made to determine where the decisions are carried out. This search technique can be simplified by using the logical characteristic of computer operation. Thus, for example, the following table shows two triggering functions which initiate the decison process. The first function is a result of a change in the system status; whereas, the second function is the result of a formal document requesting the purchase of some raw material. The logical considerations and action to be taken are shown in Table 1.

It is obvious from Table 1 that a logical comparison implies a yes-no type response. An important advantage of this method of comparison is that computers operate in a binary or yes-no mode so that this approach simplifies the computer programming as well as formalizing responses to avoid ambiguity.

This logical format for representing the decision making process is especially useful in studying problems involving a number of interacting elements. For instance, the disposition of a part for assembly was made contingent on the status of the mating parts. It is the computer's ability to update and store considerable information which permits the exploration of these considerations in such detail.

TIME LAGS IN INFORMATION FLOW

A significant aspect of the control problem is the time phasing for contingent decisions. The flow of information

can introduce time lags into a system as a result of queueing effects (6). In a sense, information flowing through a number of decision makers is comparable to jobs flowing in a factory or cars flowing on the highways. For example, if the decision maker is viewed as a processing center, the rate of arrival of decisions and the time taken to make the decision will determine the average delay or queueing effect. Where priorities are assigned the various decisions to be made, it is possible to both improve effectiveness and reduce delay times (7). Another means of reducing delays is to have alternate channels for the given decisions. Filtering or screening decisions is still another means of reducing the flow time through the system. However, this latter manner of treating decision making might lead to radical changes in organization structure and could hardly be tested initially in a real-life environment. These and related questions can readily be examined by computer simulation.

The formal and informal information channels in an organization, and the points at which decisions are made directly affect system performance. Graphically, the system effectiveness as a function of speed of response might appear as in Figure 5.

That is, for a given type decision and given organization structure and given cost there are alternate response rates which are optimal. For Case A, shown in Figure 5, the faster the response, the greater the system effectiveness. Any time lags would seriously hamper performance. On the other hand, rapid responses in Cases B and C are not nearly so critical. Thus, the information flow rate is a key parameter in system design.

Of course, speed of information flow is not a sufficient criterion of usefulness. The right information, in an understandable form and free from errors, is also a significant factor. For example, the exception principle of management is concerned with minimizing the quantity of information necessary for decision making. In a like manner, system performance information can be summarized or aggregated into more meaningful form for decision making. An important problem is determining what information is required, in what form and with what speed in order to make effective decisions and provide feedback for control. A more thorough analysis of the kinds of decisions made should yield insight as to where the computer can aid the decision maker. Routine decisions involving a large quantity of data can most easily be automated. Complex decisions involving judgment and analysis could use computers to digest information, evaluate alternatives, and test key parameters as aids in decision making.

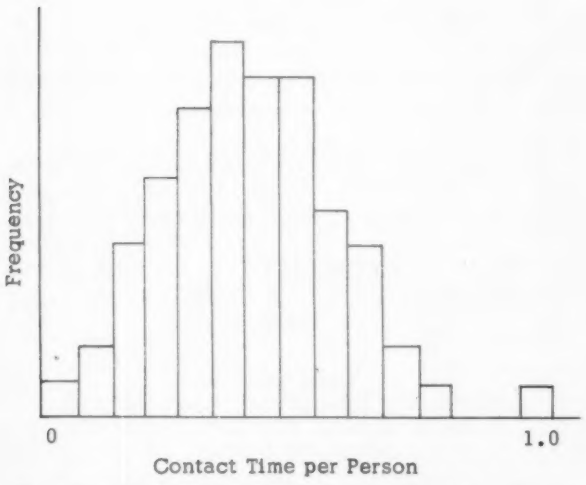

FIG. 6. Distribution of Time Supervision Spent with Personnel.

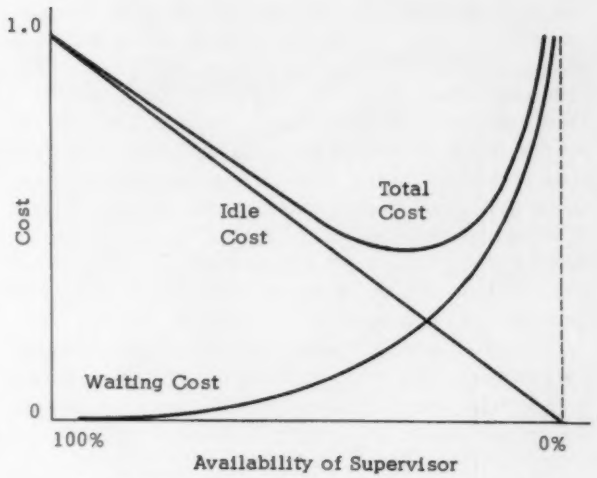

FIG. 7. Distribution of Economic Span of Control.

ORGANIZATIONAL CONSIDERATIONS

A problem related to decision making is supervisory control. Decentralized organizations require increased supervision of people. In addition, as the number of levels of organization increase, there is a greater possibility of distortion and error in information transmission. A cost function relating decentralization or numbers of levels of supervision and centralization or completely automated information processing would provide a quantitative basis for comparing alternate organization structures.

Another aspect of organization which could be explored by computer simulation is the span of supervisory control. If the elements of a supervisor's job are analyzed, it is soon apparent that a certain percent of his time is spent in direct contact with subordinates. The time spent during a contact with the subordinates would follow some distribution such as shown in Figure 6. The shape of the curve and spread or variation would depend on the characteristics of the particular supervisor, the level of persons being supervised, and the type of work performed. Thus, rather than a specific number of persons that can be supervised, the arrangement of work content and number and kind of decisions will have a direct bearing on

the problem. Since the supervisor is a decision processor, an economic span of control could be determined as in Figure 7. If the supervisor is always available (no subordinates), there would be a high idle cost; however, if there were too many subordinates decisions could be held up due to the supervisor being unavailable. This would lead to a high waiting cost. Taking the systems' viewpoint, the correct span of control would consider the cost of delays in decisions on the entire business. Since the waiting or queueing effect increases exponentially, it appears that there is an optimum availability of the supervisor which can be related to the span of conti

Thus, detail considerations of business systems behavior are necessary adjuncts to studying management controls. This becomes especially important where control is considered the means of assuring compliance with desired system behavior. Rather than establishing arbitrary bases for component control such as fixed budgets, turnover ratios, return on investment, etc., optimum total system performance should be the objective. Optimum system performance can be defined in terms of the resources available, specified goals, allowable risks, and environmental factors. In essence, the systems approach results in a joint optimization of the many facets of a business.

CONCLUSION

Research in management controls poses many challenging problems and many promising rewards. Decision rules which formalize the actions to be taken for specified conditions should improve control through predictability of response. The computer, rather than serving merely as a huge data-processing device, can be used for on-line control via simulation and data analysis. New system designs could be tested beforehand using computer simulation as the vehicle.

The process of modelling and formalizing business systems should bring clarity to the relationships of planning, policy making, and objectives to decision making and control. Rather than study control of system components, the research proposed in management controls will be conducted from the point of view of an integrated system. Thus, the research will start at the system level and incorporate components as required. As our understanding of the behavior of business improves, and decision rules are formalized, we should be in a position to design business systems with realistic objectives and improved management controls for the whole system.

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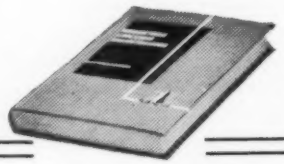

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They Live by the Clock

by **HERBERT F. GOODWIN**

School of Industrial Management, Massachusetts Institute of Technology

IF A WORK simplification program, or any other organized plan for improvement is ever going to be successful in a plant where an incentive pay system exists there must be confidence in that system. There must be a basic understanding of the procedure whereby the standards of performance are established. This usually means time study and work measurement.

When an incentive pay system does exist in any specific plant, the writer has felt it necessary to include a basic time study appreciation session as part of the series of discussions which make up the educational phase of the work simplification program. The importance of this practice becomes more apparent as the entire work force begins to actively participate in improvements.

A unique approach, inspired by an unusual experiment precipitated such gratifying results that the pattern has become the basis for all succeeding sessions which the author has conducted. Its effectiveness seems no less evident whether the group be top executives, union stewards, supervisors, production workers, or even a skilled group of Industrial Engineers.

The original group was a mixed one in a small company.[1] It included the president, 12 executives and supervisors, 4 union stewards and 3 other production workers. This experimental "Pilot Group" had been meeting one evening a week for about six months discussing work simplification philosophy and techniques and how they might be applied to this particular plant.

Time study came up for discussion at the unanimous request of the group. After more deliberation than usual the meeting was planned on the theory that since they all "live by the clock" the group should be able to develop the basic concepts themselves. What is time study? How is it used? Why is it needed? If this could be accomplished then perhaps a by-product might be understanding, confidence, and respect.

ESTABLISHING THE NEED

The meeting was opened in a typical manner with some such comment as "Since the topic for discussion today is different from Work Simplification and perhaps a highly controversial one, expect something different and perhaps more fun than usual." 3 × 5 cards were passed out, one to each person. They were asked to write their definition of time study on the card—what it was in their own words but no more than one or two sentences.

The cards were then collected and read to the group. Twenty-one different answers resulted. These were typical: "How to get more work out of the help for less pay"; "A method of wage payment" (probably the president's answer); "Piece work"; "How long it takes to do something."

The group readily became aware of the fact that no one in the room knew the exact answer to this question. It was quite a shock but the *need* for a common understanding had been established. Requests for the answer were directed at the leader. "Not so fast—Let's see if we can get at the answer ourselves from another direction."

DEVELOPING THE ANSWER THROUGH THE GROUP

"How many of you here have ever made a time study?" As if ashamed, one hand was feebly raised—that of the Industrial Engineer.

"Let's ask a different question. What time did you get up this morning?" "7 o'clock," was one reply. "Why did you get up at 7 rather than 7:15 or 6:45?" The answer came right back, "If I didn't get up until 7:15 I'd be late for work and if I got up at 6:45 I'd waste 15 minutes during which I could have been sleeping."

Another answer surprised almost everyone. "I don't get up until 7:42," said one of the union stewards. "I only live one block from the plant and never eat any breakfast, so I can just make it at 7:59—if I set the alarm for 7:42. I've really got it figured close."

A third answer did surprise everyone. "5:30," said one of the supervisors who only lived 3 blocks from the plant. Everyone looked at her for an explanation. "Well, it's like this," she continued. "I have to get up at 5:30 to get my husband's breakfast. I get him off by 6:15, since he works 12 miles from home and has to be there by 7:00. Then I get the two children dressed and get out of the house by 6:35 in time to catch the 6:40 bus at the corner. This takes me across town and lets me out in front of my mother's at about 6:55. I make breakfast for the children there, along with something for my mother who doesn't move around so well. I have another cup of coffee myself and just make the 7:35 bus back across town. This leaves me about six blocks from the plant at about 7:50 and I just get in under the wire before the 8 o'clock whistle. My husband picks the kids up on the way home so I can get home each night in 7 minutes."

[1] The company under discussion is the Signal Manufacturing Company, Salem, Massachusetts.

WE ARE ALL TIME STUDY EXPERTS

And so it went. By the time we had gone half way around the table everyone was beginning to realize that they all lived by the clock.

As we progressed the questions were changed to such as these: "Who likes to go to the ball games?" Joe raised his hand. "What time do they start?" "8:30," replied Joe. "What time do you have to leave home to make it?" "That all depends on who I go with, whose car we take and whether or not we want to see batting practice. It makes a difference." The matter was pressed further with. "What if the traffic is a little heavier than usual, Joe?" "Oh, we leave out stopping for a beer on the way or we are just late. Sometimes we don't always do as well as we should and other times we're lucky and get there early. We should make the first inning on the average if we leave by 7:10. If we leave a half hour earlier we make all of batting practice." "How do you know that's enough time?," asked another member of the group. "We've checked it many times," replied Joe, "and that's how long it should take."

THE GIVEN TASK

"Here's another question. Do any of you cook the family roast on Sunday? Mary, How long should it take to cook this 5 lb. rolled roast of beef I've drawn up here?" "That all depends again—do you want it rare, medium or well done, and what kind of a stove you have. I like it rare myself, and I use a 375° oven for 15 minutes a pound."

USE OF AVAILABLE DATA

"How did you know that 15 minutes per pound was right the first time you tried it?" "I looked it up in the cook book." "How did they know?" "They must have tried it before. As a matter of fact, you can find charts on how long it should take to cook most anything in a good cook book. They work out O.K., too."

COMMON SENSE AND GOOD JUDGMENT

"Now suppose, Mary, that your grocer does not have a 5 lb. rolled roast for you. He is all sold out. He offers to cut a 10 lb. one in half. This he does by slicing it half way down the roll, thus making a rather thin roast with a large diameter. How long would it take to cook this one, more time, less or about the same?" Mary replied that it should take a little less time because the meat is thinner and could therefore cook through faster. How did she know? She had tried one once and anyway you had to adjust the cook book a little when something a little unusual was involved.

JUST WHAT IS TIME STUDY?

And so it continued for an hour or so. How do they schedule planes, trains and buses? How do they schedule production? How do they estimate cost? How do they finish on time on a radio program? How do they balance production lines? In the end it boiled down to the fact that we all live by the clock, and all of us are pretty good at determining just how long it should take to do something. There is nothing complicated about it. Time study is just this: *"A technique for determining how long it should take to do a given task."*

USES OF TIME STUDY IN INDUSTRY

"Why should industry want to know how long it should take to do a job? What use would this be in industrial operations?" The group replied with:

Paying wages
Planning
Scheduling
Figuring how many men to hire
How many machines to buy
Balancing production
Estimating costs
Figuring how much floor space they need
Promising delivery dates
Giving the operator a goal to shoot for

This is a typical list, and the one you may develop will probably contain a few more points. But the essence of this discussion is the simple fact that industry, like the individuals in any group couldn't live without the clock. Eliminate clocks and all time relationships, and the world would soon become chaos.

WE MAKE A TIME STUDY

The best way to learn about time study is to make one. Let's make one of an actual production operation. "Who would you like most to have work for us here for the next hour while we practice making a time study?" The time study man, of course, was the unanimous choice. "OK, Fred, you just get to work putting the pegs in the board. We'll use our work simplification demonstration job, since it's one we all know, and you won't have to practice it long to get in the swing of it. Just keep working, Fred, and don't pay any attention to us."

The next few minutes can generate some rather unique responses, particularly if members of the work force are present. "How do you like it?" "You're not up to speed." "You can't keep that up." One time study man once spontaneously remarked, "Now I can understand how it feels." Another said, "It does get tiring, doesn't it?"

RECORD THE METHOD

"What is the best method of recording the 'given task' which we are going to time?" The answer returned, "How about the process charts we learned about in Work Simplification?" The Operator (or Left and Right Hand Chart) with a sketch of the workspace used would be best in this case. Maybe we don't need it in quite so much detail or the symbols may not be necessary as long as it tells the whole story.

USE FAMILIAR EQUIPMENT

A regular clock borrowed from the production floor was attached to the corner of the easel board. Once the group settled down from the hilarity of heckling the time study man, they were asked, "All right, what time is it?" Someone answered, "It's ten minutes past four." "4:10" was written on the pad. "And how many seconds is it *now?*" "It's four ten and twenty-two seconds."

TIMES ARE RECORDED

"Every time our operator finishes a cycle, and the pegs land in the box, just call out what time it is." Times were listed in a column as the group called them off: 4:10.22, 4:10.45, 4:11.07, and so on. About halfway through the recording of the times, the crayon was handed to one of the men in the group. This man wrote the times down as the leader faded into the background, where he could observe and ask occasional questions: "How is our operator doing? Is he doing a good job? Can he keep it up?"

After 25 or 30 cycles, Fred was asked to stop, and the man who was taking the readings sat down. Fred also started to return to his seat, but he was restrained. "No, you just sit right there. We'll have more work for you to do later." Another participant from the group subtracted the readings and listed the cycle times beside the existing column.

TIMES ARE PLOTTED GRAPHICALLY

Times were plotted graphically and 23 seconds was selected as the most frequent. "How many minutes in an hour?" "Sixty" the group said. "How many seconds in a minute?" "Sixty." "Then how many seconds are there in an hour?" "Thirty-six hundred." "Now, let's see. Thirty-six hundred divided by twenty-three is about 156. Then this is the production our man should make in one hour?" "No," the answer came back. "What about coffee breaks? What about pegs that don't fit? What about scratching his nose, or talking to his foreman?"

"Ah, yes . . . this, then, must be added. In most cases it is added on an overall basis. Our operator might not have had these distractions while we were observing him, so we will have to add a fair amount to take care of them. A typical allowance for light operations like this one is 10 percent, considerably more for heavy work."

"How many minutes in an eight-hour day?" "Four hundred and eighty minutes." "How much time do we take for coffee breaks?" "Ten minutes in the morning and ten in the afternoon." "How long for clean-up?" "Two minutes in the morning and three minutes in the afternoon."

"That's 25 minutes during the day when our operator isn't expected to be at his bench. Now, 10 percent of 480 is 48 minutes—a lot more than the 25. Naturally the total is more than just 25 minutes to take care of fatigue, delays, and so on. Technically it would have been more accurate if we had compared this 10 percent allowance to 9 percent of 480 minutes or 43 minutes instead of 48 since that is more nearly the way it would work out. But nobody really knows just exactly what the proper allowance should be. The important points are these: it is a lot more than the actual time away from the job, it is the same on all similar jobs, and it is consistent.

"We are not concerned with petty inaccuracies as long as we are consistent and sincere, and as long as our motives are understood. We can get along with the minor drawbacks of time study, so long as people understand it, recognize its limitations, and have confidence in its use.

"Let's see now. If we add a 10 percent allowance of 2.3 seconds to the original 23, we get 25.3 seconds. If we recalculate the hourly production by dividing 3600 by this amount we get 142 units per hour. How's that?" "That's better," the group agreed.

A SECOND TIME STUDY IS MADE

"Not so fast now. That was the first time study we've ever made. We're not going to be very good at it with only one trial. Let's make another one." This time the job was changed and two of the six rows of holes in the pegboard were covered with tape. "Now, how long *should* this job take? All right, write it down please." Two thirds of twenty-three seconds was a typical flash answer. "Wait a minute. He may take two thirds of most of the time, but let's look back at the Right and Left Hand Chart. There is one element of the job that stays the same—dumping the pegs and resetting the board for the next cycle."

Most of the group changed their estimated times by half a second or so. They were then asked to read them off as they were plotted in a graphic array on the easel. The group selected the time most frequently estimated, and Fred was once more put to work.

PRINCIPLE OF LEVELING INTRODUCED

The procedure of the first time study was repeated but different participants recorded the time, subtracted them, and made the diagram to select the time value most representative of Fred's performance. As he worked, the group was asked, "How well is he doing, *compared to the last time?* Is he working faster? Slower? About the same?" By now the time study man had improved a little through practice, thus showing a recognizable difference in the rate at which he was working. Most everyone agreed that Fred was working faster, maybe as much as 5 to 10 percent.

When this study was completed and the time selected it was found that Fred had worked a little faster than they had originally estimated. It was agreed that his time would have to be adjusted if a comparison with his previous time was to be realistic, yet they were impressed with how close they came. Judgment, they agreed, was necessary during the study. In addition to their observations with respect to Fred's speed they observed some things

about the method which had previously escaped their consideration. Perhaps the inner rows were a little easier than the outer rows. Maybe this difference was as much a factor in Fred's improvement as his difference in speed. Yes, judgment and experience in knowing what to look for were important.

The question was also raised as to which of the two speeds it was reasonable to expect Fred to maintain. Discussion of this point was postponed until later in the meeting in favor of making a third study in which they could watch more closely for both of these factors—method and speed.

A THIRD STUDY IS MADE

Two more rows of holes in the board were blocked off with tape. Again the group made their estimates. They selected the consensus of opinion after considerable discussion had ensued with reference to the relative difficulty of doing the remaining two rows. How about that constant of dumping the board? How could such a short time be accurately established? Any error in it was assuming greater proportions than it had in the first study.

Fred went to work. As luck would have it they over corrected for their previous error. They estimated he would be faster than he was. OK, it would take a while, but they would eventually "zero in" on the right time. Most of the estimates were closer this time, they had done better. How about Fred's speed?—about the same as the previous one. Their study was certainly close enough to use. "Wait a minute, could someone else perform this job at the same rate on the average?" "Just about," it was agreed, "once they got the swing of it, if all of the allowances were in there."

WE COULDN'T BE THAT FAR OFF

"How about the individual who can only make 50 percent of the expected output, or who goes way over the top?" "There must be something wrong," was the reply. "Let's watch, Fred, try the job at half speed." Everyone laughed at him it looked so slow and he didn't make it. His effort only slowed his performance down to about 75 percent of his former speed. On his second attempt to do it he only got down to 70 percent. At the other extreme when he hurried as fast as he could for just a short time his high speed and extra effort were quite apparent. The best he could do, however, was only a few cycles at 20% above his previous speed.

They readily agreed that if anyone was as far off as 50 percent slow, there must be something fundamentally wrong with either the time study, the method, or the operator. The discussion led to a brief review of other variables that could affect the ability of anyone to attain expected performance—quality, tools and materials, the job itself—there was a lot to it but nothing much really complicated.

PREDETERMINED TIME VALUES

"We almost forgot about the question of more accurately measuring that small time for dumping the board. How about it? Could we devise a cook book of basic times for fundamental motions?" "It would take a lot of research and a lot more accurate timing devices to do it but it certainly sounds reasonable," was the reply. "Several groups of people have done it and the results are pretty much the same no matter which system you use. The important thing is that they should be used in conjunction with all of the other tools we have, not instead of them and they must be applied with skill and judgment. It should be recognized that there are limits of accuracy in the use of tools of all kinds. We'll do better if we use all of the tools and keep trying to improve the old as we look for the new."

OWN STUDIES REVIEWED

"Let's look at some studies in use in our own plant. Here are some examples from each department and Fred can get particular ones from the file that anyone wants to see." The group spent the next 20 minutes looking over studies. Comments such as these were prevalent. "Now I understand it." "It's not so complicated is it?" "Makes sense." "Why didn't they tell us this ten years ago when they put in the system?"

RELATION TO METHODS AND WAGES

"How does all this affect our earnings?" someone asked. "All right, let's see if we can trace the relationship from the beginning."

"First, how are our methods established?" The opinion of the group was that Work Simplification, Methods and Technical Engineering determined these. "They are all written up in the supervisor's operation instruction book," added the plant engineer.

"How long should it take?" "This is what today's session was all about," someone else observed.

"How much should it pay?" The obvious answer came back, "More." A little serious thought and discussion, however, soon brought out the fact that this is determined by job evaluation and negotiation as outlined in the union contract. Perhaps job evaluation might be an appropriate subject for a later discussion session. Certainly it would make no difference in the standard of output established through time study whether we paid $1.00, $2.00 or $5.00 per hour for that production.

"How should this money be paid?" Here again, the systems of wage payment are numerous. A brief review of many of the typical systems resulted in the group expression that the existing piece work system was simple and easy to understand. Everyone could figure his own pay quite readily.

In summary, the following outline is shown:

How should the job be done?

Work Simplification
Methods
Technical Engineering

How long should it take?

Time Study
Work Measurement

How much should it pay?

Job Evaluation
Negotiations

How should it be paid?

Wage Payment System

SUMMARY

"In this meeting it has been our intention to oversimplify the presentation. We are not statisticians and are not necessarily technical people. Our objective has been understanding and confidence. You have developed the fundamental need for time study. We have learned about it by doing it. As used by your company, time study is basically a simple system consistently and sincerely applied to the best of their ability."

CONCLUSIONS

Participation in numerous meetings of this sort with different groups from various industries has led the writer to the following conclusions.

1. Time study is basically a simple, easily understood procedure.
2. Far too much mystery and confusion have been built into its industrial application by overly complicating its expression. This in turn has tended to render its objectives suspect.
3. Many people in the higher levels of management fail to understand the true importance of sound, consistent time study.
4. Most people, since they live by the clock, readily comprehend the fundamentals, if given the opportunity to think them through for themselves.

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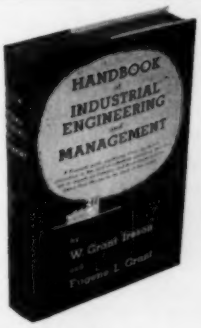

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Reader Comments

SENSITIVITY ANALYSIS IN LINEAR PROGRAMMING, by C. M. Shetty, *Journal of Industrial Engineering,* September-October, 1959.

The references listed in my article do not fully indicate the extent of prior work done in the field—in particular, the work of Charnes and Cooper who coined the name "Sensitivity Analysis." Some of the studies are indicated in:

(1) Charnes, A., Cooper, W. W., and Mellon, B., "Blending Aviation Gasolines—A Study in Programming Interdependent Activities in an Integrated Oil Company," *Econometrica,* Vol. 20, No. 2, April 1952.

(2) Charnes, A., Cooper, W. W., and Mellon, B., "A Model for Programming and Sensitivity Analysis in an Integrated Oil Company," *Econometrica,* Vol. 22, No. 2, April 1954.

(3) Heller, I., "Sensitivity Analysis in Linear Programming," Logistic Research Seminar Project, George Washington University, January 1954.

(4) Mills, H. D., "Marginal Values of Matrix Games and Linear Programs," *Linear Inequalities and Related Systems,* H. W. Kuhn and A. W. Tucker (Editors), Princeton University Press, Princeton, New Jersey, 1956.

—C. M. Shetty, Department of Industrial Engineering, The Technological Institute, Northwestern University.

NOTES ON WORK SAMPLING SAMPLE SIZE, by D. S. Holmes, *Journal of Industrial Engineering, July-August 1958.*

Mr. Louis W. Hart, Jr., Victoria, Texas, has brought to my attention an error which appeared in Figure 1, page 243. The Sample Size formula should be

$$n = Z^2(\sqrt{N-1} + \sqrt{2(N-2)})^2.$$

—D. S. Holmes, Operations Research and Synthesis, General Electric Company.

NOTES ON INDUSTRIAL ENGINEERING IN EUROPE, by T. E. Fougner, *Journal of Industrial Engineering,* November-December 1959.

Having come to Canada from The Netherlands in 1952, the above article drew my attention as soon as I spotted it in the very practical Index on the cover. I welcomed Mr Fougner's and your attempts to inform your readers about conditions and situations elsewhere. We all will benefit from looking over fences and across borders. Although I enjoy reading the notes, and appreciated the careful wording of the title, I do not agree with all of Mr. Fougner's evaluations of observations and his conclusions. Unfortunately this contribution is giving incorrect impressions in more than one aspect.

In my opinion this could be expected and consequently prevented. That's why I am writing you, knowing that you will accept and interpret my thoughts as they are intended: keeping up the standards of your wonderful Journal.

For your information I now mention first some points, where the reader does not get the total picture and thus may come to a wrong conclusion or, may insufficiently grasp the importance of the statements.

1. The "inner six" of the E.C.M. have been mentioned. The plans and activities of the "outer seven" of the Free Trade Association including Great Britain will be just as important.

2. A few very good examples of European standardization efforts have been given. The resulting lowering of production costs and improvement of the competitive position have been shown.

These results however, are only possible because all along the line from High School through University into Industry the future managers have been exposed to the value of standards. They made their school notes and their first drawings on *standardized* paper, and were instructed to use a *standard* method of indicating the diameters, lengths etc.

The continental textbooks are extremely consistent in mentioning the proper *dimensions* in *standardized* units, both in equations and answers, applying the *standardized* abbreviations. We, North Amercians, however, continue to write Ohm-cm instead of Ohm.cm for resistivity and are careless in using the sign /, which may mean almost anything, etc.

Larger industries encourage the use of *Preferred Numbers* and in general are willing to "retirer pour mieux sauter." They *want* to sacrifice some of the immediate profit in order to be able to make more money later. As a result, even the *procedures* in obtaining standards are different.

Last but not least: the decimal and metric systems are beneficial influences.

The savings from *all* these efforts together form a sizeable part of the differences in international prices. Unfortunately everybody here seems to close his eyes, does not want to listen.

3. Wages. This picture may be true for Norway, but is not necessarily so for other countries. It implies, unintentionally of course, that hardly any modern materials handling equipment can be justified in Europe. Nothing is farther from the truth.

4. Incentive plans. This is purely local experience. In The Netherlands MTM was used long before I left. The European Bedaux system is not even mentioned.

Again the, in my opinion, most important observation is missing. In Europe, in quite a few countries, the cooperation between management and labor is more apparent than in North America. Admittedly several non-related developments, such as the pressure during the war, were beneficial in making cooperation more genuine. Nevetheless the attitudes are really and substantially different. The ordinary employees of Philips' industries at Eindhoven took the initiative for erecting a statue when Dr. A. F. Philips died in 1951. Did he ever deserve it!

5. Productivity. This word has little meaning in the context, and should have ben defined. The whole section makes the reader think that drives to increase the productivity, whatever he means, were dreamed up only after the U.S.A. agencies came to the aid of the poor sucker Industrial Engineers and the sleeping managements some twelve years ago. The truth is that many countries started much earlier, but wanted the benefits of experience and increased knowledge gained by their "allies" during the second world war.

6. Education. While M.I.T. and other institutes are developing newer theories and techniques, it is clear that Europe follows. But it is not correct to make the general statements appearing in this section.

Was not Erlang Danish? Companies like "Philips" applied the economic lot size theory, the discount method for calculating returns on investments and for choosing between alternatives, long before the war. But then, they employed people like Prof. Goudriaan. Nowadays here many big companies stick to old fashioned methods, because . . . former Europeans like myself are not allowed to sell their ideas on a high enough level.

These theories and applications in turn do not go unnoticed in Dutch Universities. I do not think it makes *much* difference what name is given to the faculties and subjects or courses, as long as they are covering the subjects sufficiently. And that is what is being done. Of course, improvements are always desired, and receive attention. Statistics may not have been taught sufficiently in the past, but I studied a handbook on statistics by dr Stridiron, and do not experience now any backlog in my knowledge.

There is not only a strong *interest* in Operations Research, etc. In The Netherlands Industrial Engineering study groups, under different names, though, are and have been very *active* ever since the war. Presently an Operations Research group does exist.

8. Conclusion. Of course, there is only *one* F. W. Taylor and he was an American. Also the North America mass production methods demonstrated the need for Industrial Engineers.

I do not agree, however, with the author's conclusion in the second paragraph. European Industrial Engineers are well able to stand on their own, right now (I assume here, that the situation in The Netherlands is indicative, which I actually do not know). The point is, that they are not too conceited to learn from others. In fact, they are really *anxious* to learn. Can we say that here in North America too?

The not-to-far-future in which exchange of ideas would be beneficial, is *right now*, not 10 or 20 years hence.

We have an outmoded banking system. The Dutch P.O. clearing system should be studied. The savings would be enormous.

We can use more standardization; more system in textbooks; the decimal and metrical systems. The longer we wait, the more it will cost, and eventually we will have to change anyhow.

We need to mend our ways in dealing with labor.

We should have started systematically decreasing waste *decades* ago.

If we don't start taking European methods and systems seriously fast, the United States of America and Canada will be the loosers in the race with Europe, Japan and other countries.

Going now back to my first statement, you will understand me better when I say that it is utterly impossible for anyone, who has not lived a *long* time on the two continents, observing the right things, weighing and analyzing these, to come to the proper conclusions.

For that reason I did not contribute any articles and did not solicit any speaking engagement during the first seven and a half years of my stay in Canada. Last Monday night for the first time I compared educational systems and philosophies in The Netherlands with those in Canada. I often think of what Peter Drucker writes in his *Landmarks of Tomorrow* "The whole is not necessarily the sum of the parts. In any living organism, the parts exist in contemplation of the whole."

Team members overlooked this, or better: *could* not see it, when they wrote their reports right after the war, upon visiting the United States. They only saw the outside—the parts, not the whole. Rereading now some of these reports such as: "Management in Larger and Smaller Industries in the U.S.A.," I detect important flaws in the interpretation and analyses of facts and figures. The *time* element is very important. Did you know that in 1940, 1941 the "Adviesbureau van Ir J. M. Louwerse te Utrecht" in their organ *Bedrijfsorganisatie*, Number 5 and 6, published a similar method as published on page 423 of you latest issue: "A Simplified Approach to Waiting Lines?" The name is translated: "Manfacturing Costs when Serving More Than One Unit."

Nobody who *visits* only, is able to speak with authority because he does not know the language as if he were a native and consequently has insufficient access to the literature.

Did you read *Landmarks?* It took me several weeks, but it is very important material. But Drucker has seen more of the world than only one glorious country. He has reached the point, where he is able to evaluate impacts, to compare good and bad in many systems. Specifically I like his opinions on Education.

—Arie Verdun, Hamilton, Ontario, Canada.

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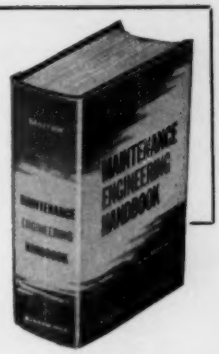

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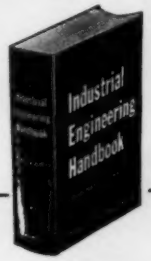

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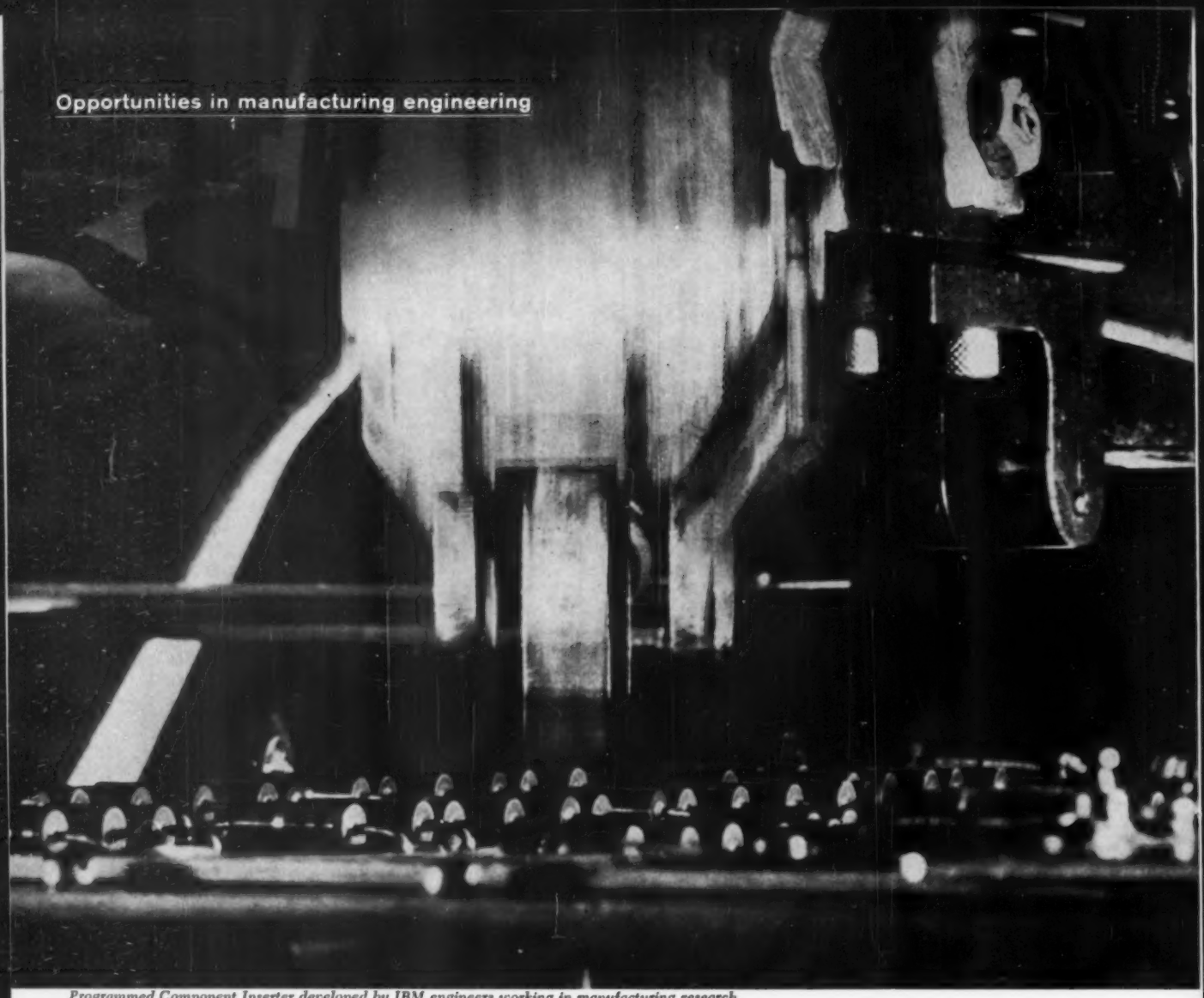

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president's message

by **FRANK J. JOHNSON**

President of the American Institute of Industrial Engineers, 1959-60

*The Sixties—A Challenge to Industrial Engineering**

LAST YEAR in his keynote address, Past President George Gustat discussed the expanding horizons of our profession. He defined a horizon as a limit of perception or experience. A problem for which you do not know the solution, is, of course, always beyond that point. As one of these problems is solved, our horizon is pushed back or expanded until we can see more and more into the future. I felt that it would be appropriate for a "Keynote" address to take a look into this future, as best we can to see the challenges facing our profession during the decade we are now entering. Before we can look ahead, it would seem appropriate that we glance back for a moment to see from whence we came.

A study of history reveals that the engineering profession probably started in the days of the Roman Empire when such projects as roads, bridges and aqueducts were designed and built, usually for the use of the armies. Between military campaigns there was time to perform the same functions for the civilian population. I guess we could say that civil engineering was the only form of engineering until about midway in the 19th century.

In 1852, when the ASCE was organized, there was but one national engineering society in the United States. Less than thirty years later, splintering began, starting with the mining, mechanical and electrical branches. This has continued until there are now some 70 engineering associations with widely varying objectives, qualifications for membership and accomplishments.

The great majority of these branches bear names that are descriptive of the type of work performed. For instance, we would all recognize the field covered by electrical, chemical, radio, ceramic and mining engineers to name a few. Industrial Engineers are not so fortunate. In fact we have spent considerable thought and time in developing a definition of Industrial Engineering for our own people as well as for the general public. The many suggested versions we received illustrate the basic problem we have within our own family. Compounding the problem is the rapid and constantly expanding scope of functions and techniques falling within the Industrial Engineer's sphere of influence. New fields of Industrial Engineering are developing so rapidly, that graduates more than three years out of school are often out of touch with the latest developments in the "state of the art."

In many ways the young engineer who has received training in the newest techniques and practices of his profession, has a distinct advantage over those of us who must strive to catch up with a rapidly advancing profession. The day of the "stop watch" engineer has passed.

These same young engineers, however, have many new problems facing them as we move ahead into the sixties. Unfortunately there has developed a trend toward collectivism, particularly as it applies to the employer-employee relationship. Of all the professions, engineering has the most members of labor unions. This trend has been

* Based upon a presentation to the Eleventh Annual National Conference of AIIE at Dallas, Texas, May 12, 1960.

the cause of some concern because society and technology have not only utilized the professional competence of the engineer, but they look to him to supply managerial and executive ability as well. Today, more than ever, the engineer must possess the technical and intellectual discernment to anticipate problems and solve them almost before others think of them. Inevitably, engineers make policy in a host of industries and vast government agencies which 10 or 20 years ago looked to the corporation lawyer, the financier, or a political figure for the lead. Just as inevitably in a period when the battle between freedom and totalitarianism is being waged, national policy must be drafted with the aid of engineers.

It would thus appear to me that the young engineer would do well to develop traits of leadership and the ability to accept responsibility if he intends to develop in professional stature. This would be difficult, if not impossible, if he remains satisfied to be subject to the leveling influence of a bargaining agency who will "represent" him in all aspects of his work relationships.

We constantly hear about the need for doing something for the "common man." Perhaps we would all be better off if we had more "uncommon" men—like Edison, Einstein, Benjamin Franklin and Henry Ford. People like this as well as many others in all fields of engineering, science and management have contributed greatly to the tremendous increase in productivity that has given our nation the highest standard of living ever known. There is only one way to continue to improve our standard of living and that is to increase productivity. While a lot of people contribute to this, it is well to remember that increasing the productivity is the Industrial Engineer's chief responsibility. This is recognized by many foreign technicians who come to our country seeking out the reasons for our so-called production "know-how." They visit our universities and seek out the Industrial Engineering Department and do likewise when visiting our industrial plants.

This recognition has been one of the main factors in the "explosive" growth of our profession. In the eleven years since AIIE was founded we have grown to a society of almost 10,000 members. In addition we have almost 2000 student members and 600 affiliates. These members are served by 104 senior chapters and 45 student chapters. More important, our growth continues at a phenomenal pace. We increase ourselves by 25% each year while creating chapters in from 10 to 12 new communities each year.

In addition to this astounding record, the attendance and enthusiasm at our chapter, regional and national conferences continue to be the envy of all other societies. This can be contributed, in part, to the predominance of young members in our Institute. This is to be expected in a profession that is relatively young. All of this has resulted in recognition by other societies and the general public. One evidence of this is the recognition by the Engineers Joint Council who only last year gave us the full status of a regular member. This recognition will continue to increase our professional status and prestige—if, we continue to demonstrate our ability to accept our professional responsibilities.

Our Long Range Planning Committee is charged with the responsibility of anticipating future problems and taking the necessary action to do something about increasing this recognition. I am happy to report that considerable progress is being made by our national organization in presenting our "professional face" to the public.

Of course the chapters and individual members present this "face" to the local community. It is to be expected that a person will judge the Industrial Engineering profession by the Industrial Engineers he happens to know. This is why it is so important for each engineer to develop himself professionally as best he can. I like to compare our profession in some ways with the medical profession. For example, if a young doctor graduated, hung out his shingle and opened up a practice, he would progress normally for awhile. However, if he did not attend symposia and conferences or study his medical journals, he would soon be so far behind in the state of the art that he would begin to lose his patients, literally and figuratively. He would be trying to treat diseases he never heard of and without the benefit of drugs and medicines that had been developed since he obtained his MD degree. The same thing happens in our profession. The engineer who has not attended a conference or symposium or who has not kept up with the latest techniques of Industrial Engineering as published in books and in our own *Journal*, will soon become an obsolete engineer. The Industrial Engineering profession is moving rapidly into new fields, such as automation, data processing techniques, regression analysis and other mathematical tools proven successful in work design.

When someone tells me our *Journal* is too technical and he can't read the articles, my first impression is that there is a man whose profession has left him behind. This, of course, does not preclude the desirability of publishing more articles of a practical nature. The proper blend is something our *Journal* staff is striving to attain.

In my visits to many chapters around the country I have had the opportunity and privilege of talking with many of our members. Perhaps the most frequent question asked me is, "What is the AIIE doing to increase our professional status and prestige?" The answer lies partially in the fine work of our many committees serving in the areas of professional development, professional relations, research, international relations, long range planning and many other equally important functions. However, I am convinced that true prestige and status will come more rapidly with recognition of ability. As each engineer develops himself professionally where he can perform a real service, he will then receive the rewards that go with recognition of ability. A successful Industrial Engineer

creates a demand for others like him. As the demand increases, all will partake of the benefits.

So much for where we are and whence we came. Let's, for a moment, look into the future and see the challenges that face us during the decade of the sixties. In my opinion, we will continue to see a rapid growth in the engineering profession and in our particular branch especially.

At present some 650,000 engineers are classified as such by the U. S. Census Bureau. The number of engineers is increasing at a rate of from two to five times that of the population as a whole. We are currently graduating about 40,000 engineers per year. This amounts to about a 6% annual increase in the number of engineers. When we compare this with our Institute's growth rate of 24%, it appears that Industrial Engineers are increasing at a rate four times as fast as other branches of engineering. This is felt to be conservative because there are many Industrial Engineers who have not joined AIIE and therefore are not included in the 24% growth curve. This increase, of course, is triggered by the increased demand for services of this nature. This explosive growth has a side effect for the more experienced engineers by creating more opportunities in engineering management which will provide the training, supervision and control of the overall engineering effort.

I predict a continuation of the trend toward newer techniques and the use of mathematical tools such as electronic computers and data processing equipment to solve the intricate problems of work design. New techniques for controlling cost of not only the manufacturing process, but the product design effort as well, will be brought into play.

Perhaps the major development ahead of us is unity in the engineering profession. The profession has no true counterpart to the American Medical Association and the American Bar Association. The National Society of Professional Engineers, which makes registration a prerequisite of membership, has about 50,000 members, or about 30% of the total number of registered engineers. At the present time about twenty engineering societies are federated in Engineers Joint Council with a combined membership of approximately 300,000. The Engineers Council for Professional Development is composed of eight societies, five of which are also included under EJC. Total membership of ECPD is approximately 200,000.

Past President L. R. Howson of the American Society of Civil Engineers very ably summarized the current status of efforts toward unity in the engineering profession at a meeting in St. Louis last year. He pointed out that while individual engineers want unity in the profession, few have defined the term in their own minds or analyzed the means by which it might be effected. The Engineers Joint Council offers the most promising hope of unity since "splintering" started nearly a century ago. The merger of ECPD and EJC into a single corporate structure is now in process, bringing unity closer to realization. Mr. Howson feels, and most of us agree, that the eventual unified organization should embrace all engineering societies, acting for them on matters of common interest but permitting each society to pursue by itself or in groups the specific activities in which it has interest and proficiency. I believe that progress is being made and will continue until unity is realized, perhaps in this decade.

I have tried to look back briefly to our accomplishments and then to look ahead to the challenges that await us in the Sixties. In looking back, I would be remiss if I did not acknowledge the excellent work of the administrations that preceded mine. I want to take this opportunity to thank all the officers, national directors, chairmen and chapter presidents for their wonderful cooperation and enthusiastic response toward the tasks we faced. That we have succeeded is a tribute to their loyalty and ability. I want to commend to you the excellent opportunity you have in the papers and panels that have been provided for your enjoyment and enlightenment at this conference. I urge you to take part to the limit of your ability. You will leave here a better engineer and you will be able to better reflect credit on our profession.

I have enjoyed my year of service as president of our Institute. I must admit that there were times that I doubted the wisdom of my decision to accept the nomination. However, in retrospect I must admit that I thoroughly enjoyed the opportunity I had of meeting so many of our members throughout this great nation of ours. Even the problems encountered as a routine part of a vast operation like ours became a challenge. I assure you that your Institute will be in good hands next year under the able and devoted leadership of Dr. Alex W. Rathe.

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Sept. 30-Oct. 1: Western Regional Conference AIIE, Salt Lake City, Utah. Write: Mr. H. D. McTague, Chairman, 1960 Western Regional Conference, P. O. Box 510, Provo, Utah.

October 10-12: An International Systems Meeting, sponsored by the Systems and Procedures Association of America, Hotel Commodore, New York City, New York. Write: Mr. David Merriman, President of the Systems and Procedures Association, 4463 Penobscot Building, Detroit 26, Michigan.

November 14-18: ASTE 1960 Western Tool Show and 28th Semiannual Meeting, Sports Arena, Los Angeles, California. (Technical sessions—Ambassador Hotel, Los Angeles, California.) Write: Harry E. Conrad, Executive Secretary ASTE, 10700 Puritan Avenue, Detroit 38, Michigan.

AIIE SCHOLARSHIPS

A news release on August 13, 1959 announced that Richard Davis Harris had been selected by the Trustees of the Dwight D. Gardner Scholarship Fund to receive their first scholarship award.

RICHARD DAVIS HARRIS

Mr. Harris, who is completing his senior year in Industrial Engineering at Virginia Polytechnic Institute, had this to say in a letter to Mr. J. L. Southern, President of the Trustees of the Fund:

"I remember with pleasure the honor of being selected as the first recipient of the Dwight D. Gardner Scholarship. The scholarship was undoubtedly the most important gift I ever received, since it meant that I would be able to continue college in uninterrupted fashion.

"It is my sincere feeling that the scholarship has done more to bring the AIIE, as an organization of men, alive to me than any other factor. The thought that AIIE is not interested in the student membership has been decidedly altered, I feel, by the awarding of this scholarship.

"As the professional organization of Industrial Engineering continues to grow, I would like to see the number of scholarship awards increase as well. I also think that thought should be given to a graduate level award. In fact, I should like to assist in forwarding this aim in any way possible when I join the senior AIIE membership ranks."

The members of AIIE who are interested in the furtherance of scientific and engineering progress and growth of the country as well as their own organization, must see in Mr. Harris' remarks the tremendous impact of this first scholarship.

A large number of applications are being received from worthwhile qualified students. These will be screened and evaluated and the recipient for the 1960-61 year will be announced in July.

"As we look ahead to the selection of this second scholarship recipient," says Mr. Southern, "we certainly must set our sights higher and plan for the time when more than one scholarship a year can be granted, making sure one of such scholarships can be for the graduate level student. I am sure this is what the membership wants and am confident it can be done through the continued support of such a highly demanded educational program."

AKRON CHAPTER

Stan Mihelick, the recently elected President of ACESS for 1960, is well known to members of the Akron Chapter of AIIE. Stan received his membership in AIIE at the time the Akron Chapter received its charter in November 1955. He served as Chairman of the Qualifications Committee during that first year, in 1956 was elected Vice President, and, with the resignation of the President who was transferred to England, served as President for the majority of that year. During 1956 the Akron Chapter of AIIE joined ACESS.

In 1957 Stan was re-elected to the office of President, and under his leadership the membership grew from 34 to 61. The treasury increased from a balance of $54 to over $400. During this year the Chapter sponsored its first Symposium.

In 1958 Stan was elected a Director of the Chapter, a position he still holds, and was Chairman of the committee which revised the Constitution of our Chapter.

It was also in 1958 that he was appointed one of our delegates to ACESS and was elected Vice President as well as serving on the Finance and Banquet Committees. And now he has been elected President of ACESS, which is not only a credit to Stan but brings honor to the Akron Chapter of AIIE.

CHARLESTON-HUNTINGTON CHAPTER

We were honored to have as guest speaker at our February meeting, Mr. Frank J. Johnson, National President of AIIE. This

Left to right, seated: J. F. Hunt, Vice President; W. L. Emmert, Director; F. J. Johnson, National President; C. G. Howard, Regional Vice President; G. F. Kahle, Treasurer; R. N. Bolling, Director. Standing: W. P. Huff, Secretary; H. L. Putney, Director; P. E. Henry, President; J. A. Riffe, Director.

being "Managers' Night" his topic, "Industrial Engineering, a Complete Shopping Center for Management" was very timely. In addition to Mr. Johnson, our guests included ten plant managers representing most of the major industries in the area. Mr. Johnson not only did a good job of selling Industrial Engineering to Management but also left the membership inspired to achieve higher goals and proud of our status in the fastest growing technical society.

CINCINNATI CHAPTER

Workshop Program May Answer Your Chapter's Problems

WHY A WORKSHOP PROGRAM?

Perhaps your Chapter now has the same problems which faced the Board of Directors of the Cincinnati Chapter back in October 1958. These problems were:

1. A lack of interest in Chapter activities. Meetings attendance average below 30% of Chapter membership.
2. Losing old members with difficulties attracting new members. Membership at this time was about 70 with little growth in past years.
3. Difficulty in filling positions for the Chapter's activities.

What it boiled down to was just plain apathy on the part of most of the Industrial Engineers in the area. Now these problems are the same to some degree in every Chapter. It's difficult to come up with a program every month which interests most of the members. It would appear that the average professional Industrial Engineer would be interested in gaining knowledge in every field of Industrial Engineering and attend monthly meetings even though the topic was not on his specific field of interest. However, such was not the case. Something else was needed besides the monthly meeting and a subscription to the *Journal* to hold the active interest of the members.

PARTICIPATING WORKSHOPS—THE ANSWER?

As a result of a recommendation from one of the Chapter members, a program was proposed in which the members would participate actively in discussion groups pertaining to *their own individual interest*. It was felt that if the members were given an opportunity to participate in an activity from which they could realize immediate benefits, they would do so. These groups called Workshops could meet monthly, perhaps right after the regular monthly meetings. If the members would realize these immediate benefits, it was felt their interest would carry over and improve the situation on all of the problems mentioned. It sounded good on paper, but would it work?

GETTING THE PROGRAM STARTED

To get things started a Workshop Chairman was appointed. Through the Chapter Newsletter, the members were given a questionnaire on which the proposed program was presented to them. They were asked to indicate if they would be interested in participating in anyone of seven possible Workshops. These seven Workshops covered just about every area in the Industrial Engineering field. The returns were encouraging, and in the Spring of 1959 a "pilot" Workshop was started. Rather than jump in feet first, it was felt that a pilot group should establish the general format to be followed. The pilot Workshop which was on Work Measurement elected to meet twice a month; one of the meetings being immediately after the regular monthly meeting. Despite a slow start and the suggestion by the Board that it meet only once a month, the enthusiasm of the group (now about 12 members) was such that it elected to continue to meet twice a month through the summer months.

With the results of the pilot group as a guide, three additional Workshops were started in the Fall of 1959; they were: 1. The Industrial Engineering Management Workshop which was open only to Chief and Supervisory Industrial Engineers. 2. The Management Services and Systems Workshop which covered systems and organization design, simulation and EDP utilization, operations research, etc. and 3. The Production and Material Control Workshop. The reception to all of these Workshops has been enthusiastic.

HOW THE PROGRAM WORKS

A chairman was elected in each Workshop who reported to the General Chairman of the Workshop Program who in turn reports to the Chapter President. Each Workshop meets at least once a month for about three hours. The size of the group is limited to 15 paid AIIE members. The subjects up for discussion are selected by the participants and fall into three categories:

1. An actual plant problem submitted by one of the participants.
2. Discussion problems of a general nature.
3. Research on new techniques or new application of existing Industrial Engineering techniques.

Minutes are usually kept by a rotating secretary and conclusions recorded. At all times, the participants cover exactly what they want to.

ADVANTAGES OF A WORKSHOP PROGRAM

1. *Increased membership*—Since the Workshop Program started, membership has jumped from about 70 to 110 in just over a year.
2. *Better membership*—The Workshops have attracted members who are willing to put some effort in the Chapter's activities. The Industrial Engineering Management Workshop in particular has been successful in bringing in key Industrial Engineering personnel in the Cincinnati area. As a result, it has been easier to fill other committee positions.
3. *Purpose to Chapter activities*—The members now can participate actively and continuously in discussion from which they can see immediate and tangible benefits.
4. *Increased meeting attendance*—By having some of the Workshops meet after the regular monthly meeting, attendance has greatly improved. In addition, the level of interest in all Industrial Engineering subjects has increased.
5. *Source of annual conferences*—The Workshop Program was used as the basis for the Cincinnati Chapter's 1959 Spring Conference which was one of the most successful in the Chapter's history. The theme is being repeated in 1960.

WHAT YOUR CHAPTER CAN DO?

The approach of our Workshop Chairman is strongly recommended for every Chapter. If you have specific questions, contact the Cincinnati Chapter—we would be glad to help you get started.

LANCASTER CHAPTER

The final meeting of 1959 was highlighted by an informative and enlightening presentation of Machine Replacement Theory by our guest speaker, Mr. Ralph O. Swalm, Professor of Industrial Engineering at Syracuse University.

A brief accounting of the year's activities showed a marked improvement in both membership and chapter activities under the direction and leadership of Chapter president Al C. McMillan. The major project for the coming season is a program in the form of a membership questionnaire asking, "How Does Your Company Correct Loose Incentive Rates or Measured Day Work Rates Without Methods or Procedure Changes?" Since every company with incentive standards is faced from time to time with "loose rates," we feel that the results of this project will be of tremendous significance.

The outstanding performance of the membership during 1959

was the basic reason why our chapter has been awarded the Regional Conference for 1960.

LEHIGH VALLEY CHAPTER

The Lehigh Valley Chapter sponsored a most interesting short course on Inventory Control on March 31 at the Lehigh Valley Club in Allentown, Pennsylvania. The course was conducted by the Operations Research Staff of Arthur D. Little, Inc. Robert G. Brown was Course Director, with Gordon J. Crook assisting. The sponsorship was in cooperation with APICS, ASQC, and NAA. This course included a review of the fundamentals of Inventory Control, the Base Stock System of Control, Exponential Smoothing, Statistical Forecasting, Controlling the System, and a Management Game to demonstrate actively just what the course meant.

The OR group at Arthur D. Little, Inc. has made nearly 50 studies of inventory problems and has developed a thorough background of skill and experience in developing practical systems of control. Many of the three dozen corporations in which these were applied feel that they have a competitive edge in service and economical operation. These practical methods have contributed to reducing their total inventories by more than $150 million while improving the routine service to customers.

LOUISVILLE CHAPTER

On December 2 at Gardner's Restaurant on Strawberry Lane, the members and their guests enjoyed a fine meeting. We were more than pleased to have as our guest and speaker Mr. Jack Jericho, National First Vice President of AIIE. Mr. Jericho gave a most interesting and timely talk on "New Concepts in Industrial Engineering," with special emphasis on some of the new systems being used by the airlines. Dinner music was furnished by the Zavala Rhythm Boys, and after dinner we were entertained by Jackie Grawemeyer on the accordion. The social hour before and after the regular meeting carried out the Christmas spirit, and provided an enjoyable evening for all who attended.

At our January meeting, the Louisville Chapter was the guest of the General Electric Company. This was a Ladies' Night meeting, so interest naturally centered around the appliance displays in Monogram Hall. After dinner we were invited to the theater of Monogram Hall to hear an interesting talk on "Cost Control Through Univac" by Mr. R. J. Bromley of the Data Processing Section of the Range Division. Then the group divided into two sections, one remaining in the theater to see some unusual slides on "Methods of Counting from Prehistoric Days to the Present Univac," while the other group went to the Univac Building where a technical demonstration of the potentialities of Univac was given. Our thanks go to Mr. Bromley and to Mr. R. M. Peterson of Data Processing, who was commentator during the movie slide, for a most unusual and entertaining evening.

NAUGATUCK VALLEY CHAPTER

The Naugatuck Valley Chapter conducted a seminar on "Selling Yourself and Your Ideas to Your Superiors" on March 24, 1960, at the Roger Smith Hotel in Waterbury, Connecticut. This successful one-day seminar was under the direction of Mr. Auren Uris of New York City. Approximately 75 members and guests were in attendance.

Although one of the most recently organized chapters of AIIE, the Naugatuck Valley Chapter maintains a full schedule of activities. Monthly Chapter meetings and Board of Directors meetings have been held since September. Thus far we have made two plant tours, one of which was in conjunction with the Central Connecticut Chapter of AIIE. Our total membership at present is approximately 45. The membership has active plans to increase this number substantially in the near future.

METROPOLITAN NEW JERSEY CHAPTER

The January meeting of the Metropolitan New Jersey Chapter was held on the 25th at the Essex House in Newark, New Jersey. Mr. Nathan Cohn, Vice President, Technical Affairs, Leeds and Northrup Company, was guest speaker. His subject was "A Visit to Russia—Industry, People, and Places." Mr. Cohn was one of a group of American industrialists who visited Russia in 1958 under the State Department's East-West Cultural Exchange Agreement. His group visited industrial plants, power plants, and technological institutes in Moscow and Leningrad. He presented to us his observations and comments on the various segments of these Russian industrial plants he toured and, since facilities answer only part of the question, Mr. Cohn also discussed and commented on the people who operate these facilities. As an added attraction, he showed us pictures of places and things often talked about but rarely seen.

Dr. Ellis R. Ott, Professor and Director at the Rutgers Statistics Center, was our speaker at the February meeting. Dr. Ott's subject was "Trouble-Shooting in a Manufacturing Plant." Some of the areas he dealt with were: methods of attaining an effective quality control program; what a total program of quality control can mean to a company; and actual case histories to illustrate how the techniques can and are working. Dr. Ott, who is vice president of the American Society for Quality Control, has served as a consultant to over a dozen of the larger companies and was Coordinator of a Quality Control Mission to India under the United National auspices.

ST. LOUIS CHAPTER

During the months of December, January, and February, the St. Louis Chapter moved in so-called "high gear." The membership crossed the 200 mark and stood at the record high of 208. The publicity committee published the first chapter newspaper, which was appropriately entitled "NUZ." The seminars, inaugurated earlier in the year, continued to be quite successful. These averaged about 45 persons for an hour-long session prior to the regular monthly dinner meetings. Topics for these three seminars were: "Practical Problems in Job Evaluation," "Job Preparation Prior to Time Study," and "Work Sampling." The last seminar featured a demonstration in which the audience made a work sampling study of an operation which was projected on a screen. The results of the studies were compared with actual time values determined from the frames of the film loop.

The dinner-meetings continued to attract large audiences. These three particular meetings had from 80 to 110 members and guests in attendance. In December Mr. Joseph Holland of the St. Louis *Post-Dispatch* enlightened our Executive Night audience with an informative talk on the growth and labor problems in the St. Louis area. Mr. Holland discussed the productivity issue and voiced the opinion that this is one area where Industrial Engineers are faced with a great challenge. He said that productivity is one of the vital issues facing our economy today.

The January meeting was an experiment which proved to be a tremendous success. Three clergymen from the St. Louis area were invited to participate in a discussion of "The Moral Responsibility of a Fair Day's Work." The speakers brought up several points to ponder: Is it fair to blame all featherbedding on the unions? Is there too much emphasis on achieving 100% effort with not enough consideration of the human element? Does management have a moral responsibility to try to find new jobs for men instead of cutting them loose as soon as their services are no longer needed? Are we doing enough to inform the assembly line worker of how his work fits into the over-all picture?

The guest speaker at our February meeting was Dr. William Gomberg, Professor of Industrial Engineering at the Wharton School of Commerce, University of Pennsylvania. Dr. Gomberg

is one of the favorite speakers of the St. Louis Chapter, and he lived up to expectations with an interesting talk on the recent steel settlement. He discussed the role of the technical man in the steel negotiations, and expressed his views as to why the negotiations bogged down over the work-rule issue. Dr. Gomberg cautioned the Industrial Engineers in the audience about entering collective bargaining without undertaking a lot of preparation in the area of union history and basic human relations.

SOUTHEASTERN VIRGINIA CHAPTER

The Union Bag-Camp Manufacturing Co. was host on January 8 to the newly formed Southeastern Virginia Chapter of AIIE. Union Bag-Camp feted the Industrial Engineers at dinner and then gave them a guided tour of the company's multi-million dollar papermaking facilities. The session was the Southeastern Virginia Chapter's first plant tour—one of several planned for the coming months according to Paul J. Davidson, AIIE chapter president.

This Chapter is the AIIE's first in Virginia, and encompasses members from Richmond, the Eastern Shore, the Lower Peninsula, Tidewater and Southside Virginia. Plans are underway to stimulate interest in similar chapters in Roanoke, Richmond, and perhaps Lynchburg.

SOUTHERN ONTARIO CHAPTER

This is the first report of the activities of the first (and, so far, only) Canadian Chapter. We have noted with interest that many of the older groups appear to make regular contributions to this section, but we were reluctant to make a start until we had moved through the formative period and had something to say.

Generally speaking, we are reasonably happy with our progress so far and our founding members can be well pleased at having introduced to Canada an organization that so readily fills a long felt need. Our membership list has risen to 93, and shows promise of continuing to develop at this satisfying rate.

We are fortunate in that our location is almost in the middle of the fastest growing industrial area on the continent, the arc sweeping from Buffalo north-east along Lake Ontario in what has been referred to in at least one large circulation business and news periodical as "The Platinum Rainbow."

The environment is one in which Industrial Engineering can thrive, both in the stimulation of new and expanded industry and the challenge it throws to older ones in the form of aggressive competition. The open Immigration policy has tempted many British and European engineers (and not a few American ones, as well) to contribute their skills to the growth of a new and energetic economy.

Yet the apparent paradox is maintained in that the paradise of the outdoor sportsman is always within reach. In some areas it is quite possible to commute from your cottage, or do a little fishing at lunch time.

WINSTON-SALEM CHAPTER

The Winston-Salem Chapter, in association with the Council of Engineering Societies of Winston-Salem, was an active participant in the local observance of National Engineers' Week. Our chapter is a charter member of the Council, which is composed of delegates from ten engineering groups responsible for the overall coordination and sponsorship of Engineers' Week observance. The chapter's present delegate to the Council is Marshall G. Bryant, who is serving as its Secretary-Treasurer.

Plans for the observance included activities for engineers and high school members of Junior Engineers Clubs in the city and county school systems. Films and speakers were available as program aids to seventeen service and civic organizations. Exhibits prepared by members of Junior Engineering Clubs, participating engineering societies and manufacturing firms were displayed. As a climax to the activities of the week, the annual dinner-dance was held on February 26. The more than four hundred people attending included members of the ten participating societies and numerous distinguished guests active in engineering, education, industry and government. Mr. George R. Herbert, President of the North Carolina Research Triangle Institute, represented Governor Luther Hodges and spoke on "Technology As The Key To Continuing Progress in North Carolina."

The Winston-Salem Chapter cooperated with the Society for the Advancement of Management in the annual Motion and Time Study Conference held March 16-18. This conference replaced the chapter's regular monthly meeting for March.

BOARD OF TRUSTEES' MEETING

CHICAGO, ILLINOIS—JANUARY 16, 1960

The Board of Trustees of AIIE is the official governing body of your organization. This group meets to conduct business for you three times a year. The official minutes of the January Board of Trustees' meeting are published in the Journal *to keep you informed of AIIE activity.*

The meeting was called to order by President Johnson at 8:45 A.M. He introduced Paul D. Chapman, Jr., the new business administrator, and Messrs. Lange and Mahaffey. Among those in attendance were: Frank J. Johnson, President; Jack F. Jericho, First Vice President; Floyd J. Titler, Executive Secretary; Ralph W. Updegraff, Treasurer; George H. Gustat, Past President; William J. Vallette, Vice President, Region I; Leroy O. Gillette, Vice President, Region II; Charles G. Howard, Vice President, Region III; John A. Nattress, Vice President, Region IV; James A. Richardson, Vice President, Region V; William N. Bryant, Vice President, Region VI; John L. Imhoff, Vice President, Region VII; Arthur E. Aronson, Vice President, Region VIII; Arthur L. Ziegelmeyer, Jr., Vice President, Region IX; Carl F. Kaiser, Vice President, Region X; Warren E. Alberts, Board Member-at-Large; James Nordahl, Board Member-at-Large; Alex W. Rathe, Board Member-at-Large; Henry M. Owades, Director of UEC Affairs, AIIE Professional Relations Committee; E. Paul Lange, Executive Secretary, EJC; Daniel Mahaffey, President, Atlanta Chapter, AIIE; and Paul D. Chapman, Jr., Business Administrator.

1. *Minutes, October 16-17, 1959, Board of Trustees' Meeting*—Dr. Rathe moved that the minutes of the October meeting be approved as presented. Motion seconded by Mr. Aronson. Motion passed.

2. **OLD BUSINESS**

2a. *United Engineering Center*—Dr. Rathe turned the discussion over to Mr. Henry M. Owades, Director of UEC Affairs, who passed out a status report on the progress of the campaign. On January 14, 1960, the AIIE's contribution for the United Engineering Center had reached $56,670.35, which is 81% of our quota. This represented slightly more than a 9% increase since the last board meeting held in Atlanta last October.

The number of "grounded" chapters has been reduced from

15 to 7. Those still on the ground are:

Birmingham	Indianapolis	Mohawk Valley
Dayton	Middle Tennessee	Western Virginia
East Tennessee		

Mr. Owades listed 8 chapters with unsubscribed pledges of $1,000 or more:

Cleveland	Chicago	Dallas-Ft. Worth
Los Angeles	Pittsburgh	Detroit
St. Louis		Cincinnati

He also stated that 50% of our chapters (excluding those which have reached their quota and the "grounded" chapters) have not been heard from in two months or longer. These "stalled" chapters are:

Fort Wayne	Eastern North Carolina	Northwest Georgia
Syracuse		Columbus
Florida West Coast	Tri-Cities	Wichita
Metropolitan New Jersey	Tulsa	Southern Ontario
	Peninsula	Miami
Atlanta	Central Arkansas	Pensacola
Albuquerque Area	Lancaster Area	Dallas-Ft. Worth
Akron	Macon	Central Arizona
Detroit	Northeastern Florida	Cincinnati
Louisville		Pittsburgh

Mr. Owades mentioned that the consulting engineers now have reached 95% of their quota and that we had lost our opportunity in the campaign of being second, but that the AIIE can still be third to make their quota. He stated that the Mid-Hudson Chapter, which is already on the Honor Roll, was the first to go over 200% of their quota.

Dr. Rathe brought to the attention of the board members, when visiting chapters who have not changed standing for several months, to encourage them to increase their efforts in this campaign.

He also noted the fact that the three convention cities, Atlanta (1959), Dallas-Ft. Worth (1960), and Detroit (1961) are in sad shape in the fund drive, and these cities are certainly in the limelight of the AIIE, publicly and with the membership.

Giving pep talks at meetings visited is one way of transmitting enthusiasm back to the chapters. President Johnson stated that until we step-up our efforts in meeting our obligations we will not achieve prestige and status as a society. Each member of the profession will benefit later on and that it is an investment in our future. It was brought out in the discussion that some of the "stalled" chapters were holding back in reporting. Mr. Vallette mentioned that Pittsburgh, one of the cities which wanted the building had made a chapter contribution only.

2b. *1960 Conference and Convention Report*—Mr. Ziegelmeyer, a member of the 1960 Conference and Convention Committee, reported on the status of the conference. He stated that everything was on schedule except money sent in for exhibits. A total of 8 booths have been sold, three to IBM. Cash balance as of December, 1959 was $1,800. Contacts for exhibits are being made at the local level. The hotel has been firmed up.

Mr. Titler announced that to date, out of 900 contacts of exhibitors, 8 booths have been sold and $2,000 collected for exhibits. He had a follow-up letter drawn up by an advertising firm, which will be robotyped, signed by him, personally, and sent to names of advertising managers. A list of advertisers from previous conerences has been developed. There are still 18 booths left to be sold.

Mr. Ziegelmeyer stated that five speakers were still needed, and although people were available to fill the spots, they were still being very selective.

2c. *1961 Conference and Convention Report*—President Johnson reported on the minutes of the latest 1961 Conference and Convention committee meeting. He has received a letter from Laurence G. Taber, Chairman of the Gantt Centennial Memorial Committee, expressing his appreciation to be Chairman of this committee. Mr. Taber requested the Board of Trustees review and comment on four basic tentative proposals, which are as follows:

Proposal I: Formation of a Gantt Centennial Memorial Committee

Proposal II: News Releases dealing with Mr. Ganntt

Proposal III: Commemorative United States postage stamp

Proposal IV: Theme for the National AIIE Convention in 1961

President Johnson requested concurrence of the Board to write to Mr. Taber. After discussing the proposals, the Board gave President Johnson concurrence to write Mr. Taber, strongly stressing the importance of News Releases to the public press. Although the theme of the 1961 Conference is "Learn by Doing," it also will highlight the Gantt Centennial Memorial.

2d. *ECPD Definition of Engineering*—Mr. Updegraff moved that the ECPD definition of engineering be approved, subject to the recommended minimum changes made by Long Range Planning Committee, and submitted to the Professional Relations Committee so that the final recommendations of the AIIE can be submitted to the ECPD by the spring of 1960. Mr. Bryant seconded the motion. Motion passed.

2e. *Unionization of Engineers Taskforce Report*—Dr. Rathe moved that the latest version drawn up by the original taskforce, subject to review of counsel, be approved by the Board. Motion seconded by Mr. Howard. Motion passed. Mr. Titler will submit the recommendations back to counsel, and upon approval by counsel, he will send it to the Winston-Salem group.

2f. *Organization Study*—Mr. Jericho presented the final draft of the new organization structure and reviewed the changes necessary to the Constitution and By-Laws in order to activate the new organization. He reviewed the corrections that had been made in title structures and other changes made since the October Board Meeting. He requested that the Board approve the new organization, and their approval of the By-Laws, subject to the adoption of the Constitution by the membership. He indicated that if the Board waited until the May meeting to approve the By-Laws changes, it would delay implementation of the new organization by the new administration.

Mr. Jericho clarified the question raised that there be a ¾ vote instead of a majority vote of the Board regarding any change of an Executive Secretary. Actually, the word change should read "removal" and the reason for using ¾ vote instead of majority was put into make it difficult to remove the Executive Secretary from office. It was agreed to correct the wording.

A motion was entertained and passed to change the word "may" to "shall" on page 3, Section 15 (proposed) of the Constitution.

Mr. Ziegelmeyer moved that the new organization structure and proposed Constitutional changes be approved by the Board. Mr. Titler amended this motion to include the submission of the Constitution to the membership for vote. Motion seconded by Mr. Nattress. Motion passed.

Mr. Gillette moved that the proposed By-Laws be approved by the Board, subject to approval of the Constitutional changes by the membership of AIIE. Mr. Bryant seconded the motion. Motion passed.

The Board concurred that Messrs. Johnson and Jericho prepare a letter to the chapter presidents regarding the new organization. It was also agreed that a story should be published in the *Journal* regarding the new organization.

2g. *Engineering Management Conference*—Dr. Rathe reported

on the 1959 Los Angeles Engineering Management Conference. Total registration was 463, and a net profit of $3,450 was realized.

Dr. Rathe moved that AIIE share with other societies the responsibility and financial planning for other Engineering Management Conferences in the future. Motion seconded by Mr. Gillette. Motion passed.

2h. *Membership in CIPM*—Dr. Rathe reported that at the December Executive Committee Meeting, it was agreed to submit Mr. Vallette's proposal to the Board to go ahead with membership. It was tabled at the October Board Meeting due to no funds available. Since that time, Mr. Vallette, Vice President of Region I, has turned back $250 of his budget with the understanding that this money be used to enable AIIE to become a member of CIPM.

President Johnson stated that the Council for International Progress in Management is the official representative to the CIOS (Comite' International de L'Organisation Scientifique) of leading U. S. management associations, such as the American Management Association, American Marketing Association, American Society of Mechanical Engineers, American Society of Training Directors, Association of Consulting Management Engineers, and the Society for the Advancement of Management. He mentioned that the Council's membership also included leading corporations and industrial firms and leading schools and colleges of business administration.

Dr. Rathe moved, on behalf of Dave Porter, that the Board approve immediate application of AIIE to join CIPM with annual dues of $250. Motion seconded by Mr. Vallette. Mr. Titler offered an amendment that the money be provided by using the $250 offered by Mr. Vallette. Motion passed.

Mr. Dave Porter will be informed of the Board's action and that application forms should be requested. Dr. Rathe suggested that the following representatives be appointed to the Board of CIPM: Dr. Lillian Gilbreath, George H. Gustat, and William J. Vallette. He also recommended that Dave Porter be appointed as an alternate. The Board voted in favor of the above recommendations.

It was decided that mail should be directed to Dave Porter, Director of International Relations. Mr. Porter shall designate a chairman of the group and determine who shall handle the various functions.

2i. *Standards of Industrial Engineering Education*—This item was placed on the agenda in error.

2j. *Appointment of AIIE Representative and Alternate to EJC Board*—Mr. Titler moved that the Board approve the appointment of Mr. Herbert Ashcroft as Representative of AIIE to the Board of the Engineers Joint Council. Motion was seconded by Mr. Vallette. Motion passed. Mr. Ashcroft thus becomes a Board Member-at-Large per AIIE's Constitution, Article VII, Section 33.

Mr. Titler also moved that the Board approve the appointment of Dr. Alex W. Rathe as an alternate to the Board of the EJC. Motion seconded by Mr. Jericho. Motion passed.

2k. *Other Old Business*

2k1. *Tax Classification Application*—Dr. Rathe made an inquiry to Mr. Titler regarding what our counsel knows about our tax classification change application. Mr. Titler indicated that one year is about up and that he would look into the matter.

3. NEW BUSINESS

3a. *Membership and New Chapter Report*—Mr. Titler reported that we now have 5577 associates and 3117 members, a total of 8694. There are 566 affiliates and 1400 student members.

One new chapter, the Capital-Berkshire Chapter, in the Albany-Schenectady-Troy area has been chartered. Those who care to write may address their letters to the President, Mr. Edward Giambalvo, 9 Ber-Tone Drive, Schenectady 6, New York.

3b. *Financial Report*—Mr. Updegraff presented the financial report stating that we are not meeting our budget as well as in previous years. About $1,000 of the emergency fund has already been used primarily due to the fact that in December we had to pay the salary of two business administrators and that from October through December the executive secretary's salary was reinstated to full pay which was not anticipated. Other items increasing the expenditures were the increase in postage due to growth in membership, and office equipment purchased the preceding year which was not included in last year's expenses. This special Board of Trustees' meeting will also affect the budget. Mr. Updegraff indicated that income is running about 16% over last year, and the increase in membership will partially offset the unanticipated expenditures. It was reported that income as of December 31, 1959 was within 5% of the budget and expenses were running about 10% over the budget.

President Johnson moved that the financial report be accepted, and the motion was seconded by Mr. Vallette. Motion passed.

3c. *Appointment of Executive Secretary*—Mr. E. Paul Lange was selected by the Board of Trustees to replace Floyd J. Titler as the new executive secretary. Mr. Lange will begin his new duties as of March 1.

3d. *Other New Business*

3d1. *Nominations for Fellow and Honorary Members*—President Johnson reported that Ed Conrad's Committee on Awards was in process of gathering information for submission of candidates to the executive committee for screening. The Awards Committee will receive all nominations, screen out those that do not meet the basic requirements, and submit the balance to the executive committee. The executive committee will screen and then submit the recommendations to the Board of Trustees by mail vote so that presentations can be made at the 1960 National Conference and Convention in Dallas.

President Johnson stated that each name submitted to E. L. Conrad for honorary member shall be proposed in writing by at least 10 members and/or fellows. The names of those so proposing may appear on one letter or in separate letters.

3d2. *International Foundation of Instrumental Control Conference*—During the meeting a phone call was received from Dr. Gordon B. Carson. Mr. Ralph Sims of Lancaster, Ohio, plans to attend the applications section of the International Foundation of Instrumental Control Conference in Moscow, Russia, the end of June and the first of July of this year. He wishes to be an official representative of AIIE and will pay all expenses.

Mr. Titler moved that the Board authorize that a letter be written for Mr. Sims, signed by President Johnson, authorizing him as an official representative of AIIE. Motion seconded by Mr. Imhoff. Motion passed. Dr. Carson will be notified and President Johnson will draw up the appropriate letter.

3d3. *Regional and National Conference Programs*—There was a general discussion regarding the invitation of union leaders as guest speakers. There have been serious criticisms in the past regarding union speakers and, if we continue, the reputation of AIIE could be damaged seriously. There is a possibility that the membership does not recognize the reasons for National's policy so the Regional Vice Presidents should try to communicate this to the chapters.

President Johnson stated that it is the policy that we do not pay guest speakers. The general thinking has been that the type of people we want usually will accept invitations at their own expense or that they will be reimbursed by their company. Mr. Jericho mentioned that this policy is not adhered to in all cases. Cases where this has been done, and the conference has operated at a loss, the loss reimbursed to the host chapter by National Headquarters cannot include the expenses paid to speakers. Dr. Rathe suggested that this problem be turned over to the Director of National Meetings for study.

The subject of all conferences is being restudied at the present time, and it was reiterated that approval of dates for chapter conferences should be obtained from the Vice President of the Region. Approval is no longer necessary from the National Director of Meetings. However, James T. French should be advised of the dates that these conferences are being held.

3d4. *Information to Past Presidents*—President Johnson suggested that Minutes of the Board of Trustees and Executive Committee Meetings be sent to past presidents. Their lasting interest in the organization should not be forgotten. Mr. Titler was directed to send information to past presidents and that it be made a policy.

3d5. *Prize Awards Regarding Submission of Papers*—President Johnson informed the Board of correspondence from Dr. C. B. Gambrell regarding prize awards of papers. He stressed that the effective handling, consideration, and acknowledgement of correspondence was very important. Each one should maintain continuity in answering mail and correspondence. President Johnson will contact Dr. Andrew Schultz and acknowledge Dr. Gambrell's correspondence as he does deserve the courtesy of having a decision.

3d6. *Investment of Funds*—Mr. Updegraff reported on a letter received from Prof. Howard P. Emerson, Chairman of the Financial Planning Committee, regarding the investigation of investment of funds. Prof. Emerson requested him to present to the Board a proposal to invest surplus funds into long-term Government Bills. Mr. Updegraff brought up certain advantages we have now, by being able to obtain money when we need it even though interest is slightly lower than Government Bills. No action was taken.

3d7. *Sickness Benefits*—Mr. Updegraff brought to the attention of the Board, Mr. Titler's prolonged illness last year. His salary was continued during that time and this income is deductible on his income tax return. A policy is presently in effect that we pay employees when they are off sick for a reasonable length of time, depending on position and salary. Mr. Titler has requested that the Board firm up this policy in writing.

Mr. Updegraff moved that Mr. Titler and Mr. Chapman draw up a letter regarding this policy and submit to him and President Johnson for signature. Motion seconded by Dr. Rathe. Motion passed.

Mr. Jericho presided over the remainder of the meeting of the Board, in the absence of President Johnson.

3d8. *Executive Secretary's Voting on the Board*—Mr. Vallette moved that a Constitutional change eliminating the vote of the executive secretary at Board and Executive Committee Meetings be submitted to the membership and that it should be placed on the ballot separately from the Constitution changes required to activate the new organization structure. Motion seconded by Mr. Kaiser.

Dr. Rathe suggested that the minutes show that we have been thinking about this change for some time, but have deferred action due to Mr. Titler.

Mr. Nattress moved to table the motion until the next Board Meeting. Motion seconded by Mr. Ziegelmeyer. Motion to table passed.

Mr. Nattress moved that the Constitution Committee look into this matter and report back to the Board in May. Motion seconded by Mr. Vallette. Motion passed.

3d9. *Special Resolution*—Dr. Rathe moved in the form of a resolution that: "Upon the impending retirement of Floyd J. Titler, the Board wishes

. . . To express its most sincere appreciation for his innumerable and valuable contributions which he has made to AIIE, in his capacities as chairman and national officer and as executive secretary,

. . . To wish Floyd J. Titler the very best in every way for every day,

. . . To voice the fond hope that AIIE may continue to benefit from his advice and counsel, his interest in and devotion to the AIIE for many years to come."

Mr. Updegraff seconded the resolution. Resolution passed.

3d10. *Journal of Industrial Engineering*—Dr. Rathe presented a letter from Dr. R. N. Lehrer, Editor-in-Chief of the *Journal*, which outlined a proposal from a publishing corporation regarding the *Journal of Industrial Engineering*. The proposal, if satisfactory arrangements regarding the editorial policies could be worked out, would make it possible for the AIIE to solve the publishing costs which are now necessary and would free up a considerable portion of the total budget for other purposes. Considerable discussion was held regarding the proposal, and there was a strong feeling among the Board members that if any arrangements are made with anyone else to publish the *Journal*, that the editorial policies must be in complete control of the present editorial staff of the AIIE.

Dr. Rathe moved that Dr. Lehrer be given Board approval to investigate in complete detail the proposal that he received from the publishing company, and that no commitments would be made until the results of the complete investigation are thoroughly analyzed and presented to the Board for approval. The motion was seconded by Mr. Aronson. Motion passed. E. Paul Lange and Robert Rice were appointed to assist Dr. Lehrer in this investigation. Mr. Jericho appointed Dr. Rathe to acknowledge Dr. Lehrer's letter and advise him of the Board's action.

3d11. *Chapter Newsletters*—A letter received from Prof. Robert M. Eastman, Chairman of the Committee on Publications Coordination and Plans, was read and discussed. Prof. Eastman requested advice on the question of developing a standard format to be followed by the chapters who publish "Newsletters." The Board exhibited considerable interest in the idea and instructed Prof. Eastman to proceed to develop such a format and submit it to the executive committee for consideration.

3d12. *Miscellaneous Items*—In answer to questions raised, Mr. Jericho clarified the role Regional Vice Presidents should take regarding student chapters. The Regional Vice Presidents should advise and take an active interest in student chapter affairs and correspond directly with Charles Brennan, Director of Student Chapters.

A suggestion was made that an opportunity to express and transmit ideas to new Regional Vice Presidents be arranged at the National Conference and Convention in Dallas. This will be done at a meeting of the incoming Board on Saturday, May 14, 1960, immediately following the close of the Convention luncheon.

The Regional Vice Presidents were reminded to follow-up on annual reports and coordinate arrangements of delegates and delegates-at-large attending the National Conference and Convention.

3d13. Dr. Rathe announced that this was the last Board Meeting he would be attending as a Board Member-at-Large. He indicated that it has been a pleasure working with this group as he has worked with other groups before. The discussion held at this Board Meeting where different opinions were voiced and pulled together in the interest of the Institute was emphasized. He expressed his appreciation for having the opportunity of serving on the Board.

3d14. The new Board of Trustees will hold its first meeting on Saturday afternoon, May 14, 1960, in Dallas, at the Sheraton-Dallas Hotel. Attendance of the present Board was requested.

Adjournment—The meeting was adjourned at 4:30 P.M.

Next Meeting—The next meeting of the Board of Trustees will be held on Friday, May 13, 1960, at the Sheraton-Dallas Hotel. This meeting will be held in conjunction with the AIIE 1960 National Conference and Convention.

The next meeting of the Executive Committee will be held on Saturday, February 13, 1960, at AIIE's National Headquarters.

Professional Relations

ENGINEERING MANPOWER AND THE NATIONAL INTEREST

I hold every man a debtor to his profession; from the which as men of course do seek to receive countenance and profit, so ought they of duty to endeavour themselves by way of amends to be a help and ornament thereunto.—"Maxims of the Law," Francis Bacon

In no other period in the great history of our country has the need for redoubled efforts by the engineering profession been as urgent. Neither has the debt of the engineer to his profession been greater or more demanding of immediate attention.

The magnitude of the debt can be partially gleaned from the following excerpts of a report issued by the Engineering Manpower Commission of Engineers Joint Council entitled Engineering Manpower and the National Interest. Mr. Clifford H. Doolittle is the Chief AIIE delegate to this Commission.

"For the second consecutive year, there has been a decline in the number of freshman students enrolling in the engineering colleges in the United States. The decreases reported by the U.S. Office of Education are 11% in 1958 and are almost 4% in 1959. This is an unexpected trend, and happens at a time when indications point to increased need for engineers in the future."

Factors of current significance are:

"Programs in engineering education have been strengthened in terms of current scientific knowledge, and facilities expanded to provide adequate opportunities for qualified students."

"Projections of increasing U.S. population, coupled with anticipated economic and industrial expansion for the next decade, indicate continued growth in science, engineering and technology. Technical manpower has increased at a much more rapid pace than the growth of the total population or the total labor force, and it is expected to continue this rate of growth."

"Demand for engineers is increasing and is expected to accelerate in the years ahead."

"The nation is committed to a world contest—the outcome of which depends to a large extent on the availability of adequate supply of engineering and scientific brainpower."

The factors that outline the current situation are presented herein to assist our able youth and those who influence them in developing an awareness and understanding of these trends. With such an understanding, it is hoped that action will be taken to insure the continued excellence of our scientific and engineering assets and to adequately provide for our future technical manpower.

ENGINEERING ENROLLMENTS

Trends

"Each year in the period between 1950 and 1957, engineering freshman enrollment in the United States increased over the preceding year. Since 1958, however, this trend has been reversed and engineering enrollment declined not only in absolute numbers but also in relation to overall college enrollment. The following data are rounded out for simplicity."

Enrollment

	Academic Year		
	1957	*1958*	*1959*
Freshman—All Colleges	729,000	781,000	827,000
% Change		+7.0%	+5.9%
Male Freshman—All Colleges	445,000	468,500	490,500
% Change		+5.0%	+4.7%
Engineering Freshman	79,000	70,000	67,700
% Change		−11.1%	−3.5%
Engineering Freshman Proportion all Freshman	10.8%	9.0%	8.8%
Engineering Freshman Proportion all Male Freshman	17.8%	15.0%	13.6%

"Enrollment in other engineering undergraduate classes had also declined."

Implications

"The Freshman enrollment decline will not manifest itself in terms of egineering degrees until 1962 and 1963. Until recently, we and others concerned with manpower problems were making optimistic projections of our future supply of engineering graduates. With declining enrollments and increased drop-out in engineering, it is obvious that these estimates are going to be revised. Below are the projections made before 1958 and our revised estimates in the light of current trends."

Engineering Graduates—Bachelor Level

	Anticipated before *Fall of 1958* (when enrollment declined)	*Estimated in 1959*
1959	39,500	38,000
1960	42,000	38,500
1961	42,500	39,000
1962	44,500	36,500
1963	46,500	35,500
Five year total	215,000	187,500
Five year annual average	43,000	37,500

Our Potential Supply

"The need for attention to engineering enrollments is accentuated by a basic problem of supply limitation. It is estimated that about 17% of a group coming of college age, have the aptitude and necessary preparation to complete undergraduate engineering or science programs, with the desired high standards of achievement. Of this reservoir, about one-half are women, and under current sociological trends they will not contribute significant numbers of potential engineering candidates—even though they possess the required abilities. This group must supply, in addition, candidates for other professions and educational pursuits requiring high intellectual capacity. For various reasons, some cannot or do not go to college. In the final analysis, about one-eighth of this group or 2% of the total age group, would actually be available for our engineering colleges."

"This represents a supply 'ceiling' of about 45,000 for the past two or three years and will not much exceed 55,000 until 1964, following which there will be substantial increases in the college age population."

NATIONAL TRENDS

Population

"The U.S. population is growing at an average annual rate of 1.5%. In 1960, it will number 180 million; in 1965, 193 million and 1975 close to 225 million."

"This expanding population will require more services and products; it will represent increased needs for engineering developments and services."

Growth of Technical Manpower

"The labor force in the U.S. has increased with the rising population. The proportion of those employed in the technical field, however, has increased even more rapidly."

"The rate of increase in engineering and scientific manpower has been much greater than that of the total population or of the labor force. Within the last decade, the labor force has increased by roughly 21% while the number of engineers increased by 65%. The upward trend of engineers per worker will, in all probability, continue because of increasing use of science and engineering in industry."

Gross National Product and Productivity

In the industrial complex of the country, rising productivity has been an essential factor in the increasing Gross National Product, which more than doubled from 1945 to 1958. "Engineering has been an important element contributing to technological developments that have permitted higher productivity. Engineers are concerned with the efficient operation of our productive resources and they will form a critical factor in determining continuation of increased national productivity."

"The rate of increase of the Gross National Product will be closely related to productivity. Current projections for the GNP to reach the half trillion dollar mark by 1961-62 and surpass $700 billion by 1970 are predicted on corresponding rises in productivity—close to 3% annually. On the other hand, lower productivity increases would reduce the estimated GNP. The productivity increases will be dependent on the availability of an adequate supply of qualified engineers."

Demand for Engineers

"Studies by the National Science Foundation have illustrated the magnitude of industrial demand for engineers. Between January 1953 and January 1959, NSF reports that employment of engineers in industry rose from 409,000 to 630,000. The five year increment is greater than the number of engineering bachelor degrees awarded in the same period—138,000. The needs—greater than the supply of graduates—have necessitated measures of substitution, however inadequate they may have been."

"Anticipated growth factors of the economy and of industrial expansion point to a continuation of this magnitude of demand, which will increase further in the 1960's. Between 12,000 and 15,000 engineering graduates are needed annually simply to replace those that are removed from the engineering work force. Since the engineering profession is a relatively youthful group the replacement number will increase annually as larger numbers reach retirement age. Less than two-thirds of the graduating classes will be available to fill new needs."

"What will the needs be? The annual manpower studies of the Engineering Manpower Commission have indicated a rising level of demand in the years ahead. From the 1959 study the following estimate of key industries will serve as an illustration. The table shows the number of engineers which companies anticipate hiring in 1960, 1963 and 1966 as a multiple of the number of engineers recruited in 1959."

	Electrical Machinery and Electronics	*Aircraft*	*Chemical Mfg.*	*Research and Develop.*	*Industry Total*
1960	1.2	2.0	1.8	1.4	1.1
1963	1.6	2.1	1.8	1.9	1.3
1966	1.9	2.5	2.1	2.6	1.5

"Looked at in perspective, such variations as have occurred due to changes in the business cycle, have had only a temporary effect on the demand for engineers. This is expected to continue to increase in the future."

New Fields of Science and Engineering

"A great part of the industrial growth has been accomplished because of scientific discoveries and engineering breakthroughs that have been made since World War II. New fields have been created—nuclear energy, oceanography, electronics and instrumentation, space propulsion, chemical fuels, etc. while industrial processes have become increasingly more complex."

"These developments have generated new demands for creative engineering talent, which will multiply as new scientific findings are applied to productive enterprise."

Manpower and National Policy

"The U.S. and other nations face the same phenomenon—the increasingly technical character of modern civilization, with resulting demand for scientific and engineering manpower."

"The U.S.S.R. has recognized this trend and its implications and have adopted direct methods to handle the technical manpower problem. Through the deliberate channeling of youth into desired fields, almost one half of its college enrollment—both men and women—are in the fields of science and engineering. For the next five years, over 100,000 engineers will graduate annually."

"Under the American democratic concepts of freedom of individual choice, such state organization for allocation of human resources is precluded. The nation must find other means of filling its needs and developing its resources. These needs are different in magnitude from those of the U.S.S.R. but the basic problem is similar—that of developing enough high quality engineers and scientists for our increasing technical society. This can and must be accomplished through national effort by the engineering and scientific professions, private industry, educational institutions and the public—and without government fiat."

CONCLUSION AND ACTION

"No one can foresee the exact outlines of the future, but general trends can be perceived and acted upon. As we enter the decade of the 1960's the following is discernible:

1. Our increasingly technical world will rely for progress on engineers and scientists to a greater degree than ever.

2. Additions to the engineering manpower resources—new engineering graduates—will not be increasing and, in fact, will decline slightly in the years immediately ahead."

"Whether or not the country will have in the future sufficient quantity and quality of engineering manpower will depend on what actions and decisions are made now and in the immediate future."

"In this context, two basic objectives must be sought: our available manpower must be utilized effectively, and the supply of new graduates must be made sufficient for the expanding needs."

"To these ends, the Engineering Manpower Commission advocates:

A. Continuing attention by all sectors of the economy to improve the utilization of scientists and engineers, by insuring that those gifted with creative brainpower are committed to the challenging work at the highest level of their capacity. Placing greater emphasis on the role of engineering technicians—their training and employment, since they can contribute substantially to the overall technical task and can be drawn from a somewhat larger segment of each age group.

B. Increased recognition, in the formulation of national policy, of the vital role that engineers and scientists will play in the nation's future.

1. Higher status for technical manpower planning in the Federal Government and a new National Manpower Resources Study at the White House level.

2. Statutory provision of a new concept of service to the nation, wherein engineers and scientists may discharge their obligations

through either civilian or military service as the public interest and the national welfare may require.

C. Continual improvement in the quality of education at all levels—elementary, secondary and collegiate—and in the standards, salaries, and recognition of teachers to secure their highest competence.

1. Appropriate recognition of the role of science and mathematics—as a part of basic education—in our elementary and secondary systems and the elevation of standards under which teachers work.

2. Support of the efforts of our institutions of higher education to elevate standards and training levels and salaries of their faculties.

D. Improved communications with the public on our technical education and manpower needs.

1. Explaining the nature of engineering and scientific education, their purposes, values and requirements.

2. Conveying to parents, counselors and students clear concepts of the background preparation and other requirements as well as opportunities in the technical fields.

3. Distinguishing in communications with the public between science or scientific pursuits and engineering, particularly within the Federal Government wherein engineering and its achievements are sometimes incorrectly designated as science and even less appropriatly as 'technology.'

4. Improving the guidance and counseling activities of the professional societies and other organizations to insure that able students have a full opportunity to consider engineering education and to prepare adequately for it. Increased emphasis and support of the guidance activities of organizations such as the Engineers' Council for Professional Development and the Junior Engineering Technical Society."

"The Engineering Manpower Commission will strive toward the achievement of these objectives and recommendations and will issue statements to further amplify its views. It invites the support of organizations and individuals concerned with the vital problem of fully developing our engineering manpower resources."

Our duty is clearly evident.

Prepared for Professional Relations Committee
By Harry L. Davis

RESEARCH INFORMATION

Once a year the Research Information Committee of the American Institute of Industrial Engineers requests that research sources submit research performed in the area of Industrial Engineering. Sources from which information will be solicited are universities, industrial organizations, research institutions, and non-profit organizations, including government agencies and professional societies. These research abstracts are published annually and provide a valuable service to both industry and universities. Research abstracts are to be collected in the areas of: *Work Measurement, Methods, Plant Engineering, Human Engineering, Engineering Economics, Organization Planning, Industrial Statistics, Production Control, Data Processing, Operations Research, Cost Analysis* and *Industrial Engineering Education.*

The committee will appreciate all information on Industrial Engineering research past and present, about which it might gather abstracts. Write: Dr. Jay Goldman, Chairman, Research Information Committee, AIIE, Department of Industrial Engineering, Washington University, St. Louis 5, Missouri

recent readables

NEW PUBLICATIONS

INSTRUMENTATION ABSTRACTS, *Charles D. Lowry, Jr., and S. T. Preston, Jr.*

On January 1, 1960 a new comprehensive abstracting service was inaugurated, covering the entire field of instrumentation, *Instrumentation Abstracts.*

The objective of *Instrumentation Abstracts* is to cover all significant articles on instrumentation which may be of interest to technical personnel in the chemical, petrochemical, petroleum food, steel and glass industries. The abstractors hold technical degrees, some for graduate work. They will be guided by outstanding experts in the field of instrumentation.

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THE ENGINEERING ECONOMIST, *published quarterly by the Engineering Economy Division of American Society for Engineering Education.*

This covers current articles and book reviews on Engineering Economy, also other items of interest to the Engineering Economist.

Correspondence pertaining to subscriptions and changes of address may be sent to Laura Corridon, Business Manager, *The Engineering Economist,* Stevens Institute of Technology, Hoboken, New Jersey.

AUTOMATION

"Automation Programming for Automatic Computers," Mitchell O. Locks, JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION, *Page 744, December, 1959.*

Anyone who attempts to process data or perform computations with an automatic digital computer encounters the obstacle of preparing a detailed program in computer code and checking this program out on the computer.

Tedious preparatory work is necessary to treat a statistical or data processing problem when using an automatic electronic digital computer.

This work presents a dilemma to the analyst such as the statistician.

The purpose of automatic programming is to reduce this barrier between the user and the computer.

Mr. Locks skillfully develops his case for automatic programming as a useful tool for statisticians in the application of digital computers to computations and data processing.

"Process Control System," Fred D. Marton, INSTRUMENT AND CONTROL SYSTEMS, *Page 1714, November, 1959.*

Measurement of thickness of translucent sheet material such as paper, sheet metal, plastic, coated fabrics, etc. is done by thickness gages using beta rays radiating from radioactive isotopes.

Have the advantage of not contacting material, therefore, leaves no trace on it.

"Data Loggers," Milton H. Aronsen, INSTRUMENT AND CONTROL SYSTEMS, *Page 1672, November, 1959.*

This survey of loggers shows the great variety of types and sizes available to the user.

"Computer Control Philosophy," C. E. Mathewson and B. White, INSTRUMENT AND CONTROL SYSTEMS, *Page 1830, December, 1959.*

Differences between data logger and on-line process digital computer explained and difference between analog and digital computers outlined.

COST CONTROL

"Budgeting in Large Manufacturing Corporations," Willard E. Stone, ADVANCED MANAGEMENT, *Page 10, February, 1960.*

Results of a survey among 332 large manufacturing corporations add to our knowledge of current budgeting practices in several major areas—use by size of company, use by particular industry, complete forecasting and budgeting by organization units.

ENGINEERING ECONOMY

"The MAPI Urgency Rating," Myles M. Dryden, THE ENGINEERING ECONOMIST, *Page 13, Summer, 1959.*

This article deals with the consideration of one of the more recently devised ranking procedures in Capital budgeting. It considers the ranking criterion which George Terborgh advances in his new book, examines the assumptions and evaluates them.

"Engineering Economy—Teaching and Practice," Billy E. Goetz, THE ENGINEERING ECONOMIST, *Page 1, Fall, 1959.*

The following sequences of topics are covered:

1. The desirable content of a course in engineering economy.
2. A general model of the investment (and replacement) problem.
3. Considerations in the determination of the critical rate of interest.
4. Stability and gradients as factors in estimating receipts and disbursements.
5. The paramount importance of the use of field work.

"A New Approach to the Determination of Replacement Costs," Dr. Francois J. Olmer, MANAGEMENT SCIENCE, *Page 111, October, 1959.*

The new approach determines minimum average costs more simply and accurately than through the classical estimation procedures by omitting the obsolescence gradient and/or the economic life of the equipment from the formula. Rather, the time adjusted minimum average costs of an industrial equipment or process are expresed in terms of the logarithmic decrement of its salvage values.

"Project Justification in a Multiproduct Chemical Plant," Andrew Tsu-chao Chang, THE ENGINEERING ECONOMIST, *Page 13, Fall 1959.*

This article discusses the reasons for equipment acquisition and replacement in the chemical industry, and presents the method used by a large dye and pharmaceutical plant, of a leading chemical company, in the economic justification of projects involving large sums of money.

GENERAL

"The Myth of the Organization Chart," Clarence B. Randall, DUN'S REVIEW AND MODERN INDUSTRY, *February, 1960, Page 38.*

In this very amusing and entertaining article Mr. Randall discusses the danger of permitting the "Organizational Chart" to usurp the prerogatives of your management people. The article deftly and impressively exposes the perils of the organization-chart mentality and shows how they can be overcome.

"The Next Decade in Management," Peter F. Drucker, DUN'S REVIEW AND MODERN INDUSTRY, *Page 52, December, 1959.*

Mr. Drucker adds another typically objective and thought provoking article to his long list of publications concerning management and management problems.

This article lists and discusses four crucial management challenges facing us in the next decade. Management's success in the coming decade depends upon how well it discharges its responsibilities in these four areas.

"Pros and Cons of Professional Editors," CHEMICAL WEEK, *Page 53, January 2, 1960.*

This article discusses a most timely and profound question in a most enlightening manner.

Research report editors are showing up in more industry and government labs. It also shows that a lot of big chemical companies still don't use them, and in pin-pointing the reasons why, the survey gives useful ways to judge whether your company could use such editors, and how.

"Mechanized Maintenance Scheduling," Henry G. Snider, PLANT ENGINEERING, *Page 101, January, 1960.*

This article presents a careful, step-by-step answer to the question "Where do we go from here?" Once the decision has been made to use a mechanized system for scheduling maintenance of equipment, machinery and buildings. Developed by the faculty of the Civil Engineering Center for the United States Air Force, and in successful operation for several months, this system can be set up on any type data processing equipment and used in any industrial plant.

"Everyone Participates in Work Simplification," Herbert F. Goodwin, ADVANCED MANAGEMENT, *Page 12, December, 1959.*

People can be taught to use the tools compatible with their level of activity. They also can learn to recognize the need and request service from those with other capabilities. . . . This is the organized use of common sense.

"Frederick W. Taylor and the American Philosophy of Management," Ralph C. Davis, ADVANCED MANAGEMENT, *Page 4, December, 1959.*

This is an address given by Professor Davis upon receiving the 1959 Taylor Key Award of the Society for Advancement of Management. Presentation of the Award was made at the Society's Annual Fall Conference, October 29, 1959.

"How to Get More for Your Maintenance Dollar," THE IRON AGE, *Page 93, December 10, 1959.*

The answer isn't in the number of maintenance dollars a company spends. It's in the way the money is spent. The major factor is the balance of maintenance cost against the production efficiency of the machine in question.

"Compensation, Logic and the Market Place," Walter Sikes, ADVANCED MANAGEMENT, *Page 24, February, 1960.*

A commonly accepted principle in American industry is that employees should be equitably paid according to the relative difficulty or demand of their jobs. Within a free enterprise system rationality in terms of economic reward can be applied only in a limited area.

"Are Organization Men Wanted?", THE IRON AGE, *Page 74, February 18, 1960.*

Managers with initiative and daring are in demand—not the conformists, according to a survey of top companies.

Safe, group thinking actually works against growth and competition.

"Sound, Noise and Hearing," Nelson Hartz, INSTRUMENT AND CONTROL SYSTEMS, *Page 249, February, 1960.*

Explanation of criteria used to evaluate possible harmful and costly effects of excessive noise and to define what noise level is excessive. Deals with fatigue and occupational disease costs to industry.

MATERIAL HANDLING

"Cutting Order Picking Costs," by Editors, MODERN MATERIAL HANDLING, *Page 103, January, 1960.*

Order picking accounts for the largest single element of operating cost in most warehouses. Much can be done via improved management methods and smart engineering. This special report covers three basic approaches and describes four outstanding applications.

"A Look at Dry Bulk Handling," E. W. Geigel, MATERIAL HANDLING ENGINEERING, *Page 79, February, 1960.*

The author discusses the equipment and costs required for palletized units, bulk boxes, metal bins, rubber bins, bulk trucks, and hopper cars. He lists the distinct advantages of each system.

OPERATIONS RESEARCH

"New League for Business Games," G. J. McMasus, THE IRON AGE, *Page 49, February 4, 1960.*

Players will take control of three imaginary companies. Computer will decide who wins.

The college says its game is complex enough to be of real value.

"Input Distortion and Observer Overlap in Decision-Making," S. J. Kidd and Fred Boyes, MANAGEMENT SCIENCE, *Page 123, October, 1959.*

A realistic decision-making situation was developed based on the simulation of a tactical military operation by a three-man team, consisting of two information gatherers-reporters and one information integrator-decision maker. They demonstrated through experiment the distortion that results when information is summarized and communicated through several levels of subordinates to the executive. This distortion could not be overcome by requiring that information was available from two or more observers.

QUALITY CONTROL

"Quality Control Engineering in New Designs," W. J. Masser, INDUSTRIAL QUALITY CONTROL, *Page 10, January, 1960.*

Stresses the contribution a quality engineer must make before design of a product is completed or before process is established by which it will be made.

SYSTEMS AND PROCEDURES

"How Forms Simplification Improved Order Handling," George Hano, THE OFFICE, *Page 20, March, 1960.*

The shoemaker's children are sometimes illshod. When a forms manufacturer combined its own forms, it got the kind of methods improvement that its customers had been getting for a long time.

"Effective Methods of Expense Control," Henry L. Wylie, THE OFFICE, *Page 104, March, 1959.*

The seventh in a series of articles covering the basic office functions, showing how office methods can be improved—especially in the medium sized and smaller company.

WORK MEASUREMENT

"The ABC's of MCD-Part 1," S. A. Binn, OFFICE MANAGEMENT, *Page 11, February, 1960.*

The measurement of office work by use of Master Clerical Data which is based on MTM. Compares with time study and film analysis.

- HOW FOREMEN CAN CONTROL COSTS
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ie opportunities

The I.E. Opportunities service is a functional committee activity of the AIIE. Information concerning employment opportunities is collected on a nationwide basis and is provided without charge to members upon request. The committee is composed of members from the Columbus, Ohio chapter.

SERVICES PROVIDED

Current job openings are published in condensed form in each issue. In addition, a monthly I. E. Opportunities Bulletin is supplied to over one hundred chapters located throughout the U.S.

Each job opening is assigned a **"P"** number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the address below: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available just prior to press time. If you would like more information about one or more of the positions listed, mail the **"P"** numbers with your name and address to the Opportunities Service at the address below. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

ADDRESS OF THE SERVICE

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American Institute of Industrial Engineers
145 North High Street
Columbus 15, Ohio

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		
						Years of exp.	Age range	Remarks
41	Consulting	Ohio	×	10, 21, 31		5–7		
167	Weapons Systems	Wash. D.C.		50				Ph.D.
213	Air Force	Calif.		15, 32, 42, 43, 44, 53	7.5–	2½–	21–	Repair & Modification
273	Air Force	Utah		11, 13, 18, 42, 43, 44, 53	6.3– 7.5	2–		I.E. Degree
279	Air Line	Ill., Colo., Calif.		11, 13, 18, 41–43, 50–52, 70	5.0– 8.5	1–6		
308	Automotive	Pa.		19, 31, 36, 38, 45, 53, 71	6.7– 9.7	3–7		
339	Automotive	Pa.		10, 22, 23, 32, 33, 36, 38, 42, 45, 71	6.7– 9.7	3–7		
340	Automotive	Pa.		11, 13, 22, 23, 32	5.5– 7.9	0–3		
376	Education	Mass.					35–	
419	Food Processing	Ill.		14, 15, 16, 22, 36, 38, 91	7.2– 9.0	5–8	30–38	I.E. or M.E. Degree
423	Air Force	Ohio		Broad	8.8			I.E. Degree
424	Air Force	Ohio		Broad	4.5– 7.5			I.E. Degree
449	Electronics	Mass.		30, 50, 70	6.0– 8.0	1–5		
461	Paper	Ohio	Ltd.	10, 20	9.0–13.0	3–5	–45	Tech. Deg. Req.
464	Consulting	N.J.	×	10, 20, 32–34, 42, 43, 54, 71–73, 92	8.0–12.0	5–	30–36	I.E. Degree
465	Consulting	Mass.	×	10, 20, 30, 40, 60, 71, 92	11.0–15.0	10–	35–45	I.E. Degree or Equiv.
470	Mining & Smelt .	N.M.		11, 13, 26, 36, 42, 45	5.0–7.0		–45	I.E. Degree Preferred
472	Plastic Prod.	Va.		11	8.0– 8.5	1–2	–30	MTM Experience (Woodworking)
473	Electronics	Iowa		19, 30, 40, 50	7.2–	0–10		B.S. or M.S. Degree
474	Food Processing	Ill.		14, 15, 16, 22, 36, 38, 91	5.8– 9.0	0–8	25–35	I.E. or M.E. Degree
476	Metalworking	Ohio		13, 15, 36, 37	7.0–	2–5	25–30	
477	Metalworking	Ohio		53		2–5	25–30	
479	Brass Products	Conn.		10, 20, 36		1–5		Math. Experience
487	Electronics	Tex.		11, 16, 30, 32, 36	6.0–8.5	1–5	24–35	I.E. Degree
489	Refining	Tex.			10.0–12.0	10–15		Exp. in Crude Oil Act.
491	Airline	Ill., Colo., Calif.	15%	11, 13, 18, 51, 70	5.0– 8.0	1–5	–40	I.E. Degree Pref.
493	Plumbing Supplies	Ohio		11, 13, 18	7.5– 9.0	7–	30–35	I.E. Degree
494	Electronics	Utah		10–18, 34, 36, 40–46, 91	7.5– 9.0	5–10	30–40	I.E. Degree
495	Education	Fla.		Asst. Professor	Open	5–	30–	M.S. or Ph.D. Pref.
499	Electronic Equip.	N.Y.		10, 36	Open	3–		I.E. Degree or Equiv.
503	Electronics	D.C.		30	9.0–11.7	5–		I.E. Degree
506	Railroad	Pa.		11, 13, 31, 36, 42, 43	5.7– 7.2	0–2	24–30	I.E. or I.M. Pref.
507	Railroad	Pa.		31–38, 51–53	7.2– 9.6	2–5	24–35	I.E. or I.M. Pref.
511	Pharmaceutical	Mich.		General		0–5		I.E. Degree
514	Air Force	Ohio	25%	12, 17, 18	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
515	Air Force	Ohio	25%	40	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
516	Air Force	Ohio	25%	32, 37	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
517	Air Force	Ohio	25%	10, 13, 16	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
518	Air Force	Ohio	25%	Broad I.E.	8.8–10.0	4½–		B.S.I.E. or M.S.I.E.
519	Automotive Parts	Mich.		10	6.0– 9.0	3–5		College Degree
520	Automotive Parts	Mich.		30	6.0– 9.0	3–5		College Degree
522	Ind. Fastenings	Ill.		11, 14, 15, 19, 36, 38, 43, 45, 71	6.0– 7.8	1–3	–35	
524	Utilities	D.C.		10, 13, 17, 37	6.0– 7.0	2–3	28–	I .E. Degree
527	Consulting	Ind., Ill., Minn.	×	15, 22, 31, 41, 53, 91	9.0–12.0	10–	35–50	I.E. Degree Pref.
528	Farm Cooperative	N. Y.	×	Broad	8.0– 9.0	5–7		I.E. Deg. Plus B.A. Train.
530	Paper Prod.	Mo.	×	15, 21, 36, 38, 42, 53, 54, 70	6.0–10.0	2–5	24–35	I.E. Degree
531	Consulting	Ohio	×	40, 50, 70, 80, 90	Open	5–15	25–40	B.S. Degree
532	Metal Fasteners	Pa.		11, 15, 19, 26	7.9– 9.0	5–10	28–40	
533	Chemical-Plastics	N.J.		31, 35	Open	4–	35–50	Prod.—Inv. Control Exp.
534	Glass	N.Y.	½	11, 42, 43, 44, 45, 46, 47	7.0–	5–	30–40	I.E. or M.E. Degree
538	Papermaking	Pa.		50, 51, 52, 53, 55	9.0–11.0	3–5	25–35	
539	U. S. Army	Ill.	×	37, 52, 54	7.5–11.0	2–4		B.S. Degree
541	Communications Mfg.	N.Y.		13, 43, 81	7.5– 9.5	3–	30–40	I.E. Degree or Equiv.
542	Electronics	N.Y.		19, 42, 43	5.2– 8.5	0–3		B.S.—I.E., I.M., or M.E.
543	Air Force (Maint.)	Pa.		11, 13, 18, 44, 53, 91	7.5	4–	25–40	I.E. Degree
545	Consulting	Pa.	×	10, 20, 30, 40, 50, 70, 90	8.0–12.0	5–	28–40	
546	Consulting	Ill.	½	Broad	8.0–12.0	5–	28–40	
552	Smelt. & Titanium	Canada			7.0– 8.5	5–10		
553	Sugar Refining	Md., La.		11, 36, 38, 43	6.2–9.0	0–5		I.E. Degree
555	Office Machy.	Mich.		11, 30–37	9.6–	3–	30–40	Exp. in System Analysis
556	Office Machy.	Mich.		30	9.6–	3–5		Exp. in Quality Control
557	Corrugated Boxes	Tex.		10, 21–23, 26, 42, 60	6.0–	2–3	23–34	I.E. Degree

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1.000	Qualifications required		
						Years of exp.	Age range	Remarks
558	Food Processing	Minn.		36, 38		2–		I.E. or I.M. Degree
559	Machine Tool Mfg.	Wis.		Project Engineer	Open	0–3	Open	B.S.M.E. or I.E. Equiv.
560	Machine Tool Mfg.	Wis.		Tool Designer	Open	3–5	Open	Degree not Necessary
561	Navy	S.C.		11, 15, 17, 18, 52, 71, 90	7.5– 8.2	2½–		Degree
563	Needles	Mo.		92	9.0–10.0	8–10	30–	College Graduate
564	Education	N.D.		30, 40, 50	7.0–	8–	40–50	M.S./Ph.D. or P.E.
566	Education	Mo.		10, 30, 40, 50	Open			
567	Lumbering Mfg.-Cut Parts	La.		10, 30, 32, 33, 40, 48, 94	4.5– 6.5		25–40	
568	Motor Freight	Minn.		43, 81	8.0–12.0	5–10	30–40	Degree in I.E. Pref.
569	Transportation *(See Below)			10, 30, 42, 43, 47	8.4– 9.6	7–	30–	I.E. Degree
570	Transportation *(See Below)			10, 30, 42, 43, 47	7.0– 8.4	4–	20–	I.E. Degree
571	Transportation *(See Below)			10, 30, 42, 43, 47	6.0–	None	20–	I.E. Degree
572	Mgmt. Consultant	U.S.A. & Europe	X	10, 11, 13–18, 21, 22, 91 or 92	Open	5–	30–40	MTM Experience
573	Consulting	Ohio	Ltd.	10, 20, 30, 40, 50	Open	3–	25–	P.E. or E.I.T.
574	Aircraft Parts—(Mach.)	N.J.		10, 11, 13–16, 18, 36, 91	9.0–12.0	8–12	32–45	Engineering Degree
575	Specialty Papers	Mass.		11, 21, 36, 38, 41, 43, 67, 92	7.0–10.0	6–8	30–40	I.E. Deg.—Paper Ind. Exp.
577	Meat Packing	Minn.		10, 11, 13, 22, 38	5.0–	0–2	–30	I.E., M.E., or B.S. Degree
578	Education	Ohio		50–54			Open	M.S./Ph.D.—M.E., I.E., or Applied Math.
579	Pharmaceutical	Ill.		36		3–5		I.E. Degree or Equiv.
580	Solid Propellants	Tex.		11, 12, 19, 32, 34, 41–43, 53	7.0–10.3	2–4	25–35	B.S. in I.E. or M.E. Pref.
581	Paper	Ga.		11, 13, 21, 42 (91 or 92 Exp.)	12.0–15.0	3–	35–48	M.S.I.E. Pref., B.S.I.E. Accep.
582	Paper	Ga.		43	7.5– 8.5		30–40	B.S. in I.E. or I.M.
583	Plastic Molding	Mass.		11, 13–16, 18, 22, 42	7.2–			I.E. Degree
584	Chemical	Pa., W.Va.		11, 18, 38, 52	7.0–	3–	25–	B.S. Degree
585	Garment Mfg.	N.J.		10	5.2– 5.7	0–2		I.E. Degree
586	Glass Containers	Ind.		10, 11, 13, 14, 16, 21, 31, 36	6.3– 7.5	2–5	22–35	
587	Naval Avionics	Ind.		11, 30, 40, 70	6.2– 7.5	2–4		I.E. Degree
588	Printing	Ohio		10, 20, 30, 40, 42, 43	Open	2–7	–30	I.E. or M.E. Degree
592	Paper Converting	Ohio		10–19, 36, 38, 40–49, 53	6.3– 9.0	Open	Open	I.E. or M.E. Degree
593	Metal Working	Mich.		10, 11, 13, 20, 39, 42	10.0–	10–		Engineering Degree
594	Chemical Mfg.	Tex.		11, 30, 32, 34, 43	7.0– 9.5	2–6	27–40	B.S.I.E.
595	Plastics	Ill.		11, 42–46	7.2– 8.4	5–		B.S.M.E. or B.S.I.E.
596	Mining & Refining	Aris.		11–13, 18, 26, 28, 35, 36, 38, 48	6.5– 9.0		–40	
597	Needle-Plastics	Dela.		11, 14, 15, 19, 22, 26, 42, 48, 91	7.9– 9.5	4–	28–35	B.S.I.E. or B.S.M.E.
598	Needle-Plastics	Dela.		31, 33, 35, 36, 43, 71, 73, 91	7.9– 9.5	4–	28–35	B.S.I.E. or B.S.M.E.
599	Nonferrous Metal Fabr.	Conn.		10–14, 17, 18, 20–22	5.0– 7.0	Open	Open	I.E. Degree Preferred
600	Rubber	Pa.		11, 13, 16, 21, 36	6.0– 7.2	3–5	28–45	
601	Wood and Plastics	Va.		21	7.5– 8.0	2–3	25–35	B.S. Degree
602	Education-Teaching	Mich.		13–16, 18	7.0–	3–5	25–50	B.S., M.S., or Ph.D. in I.E. or M.E.
603	Education	Mich.		30—in Die Casting or Plastics	7.0–	3–5	25–50	Same as above
604	Education	Mich.		30—in Metal Cutting	7.0–	3–5	25–50	Same as above
605	Education	Mich.		39	7.0–	3–5	25–50	Same as above
606	Education	Mich.		50–54	7.0–	3–5	25–50	Same as above
607	Elect. Controls	Mass.		30,32,39	10.0–12.0	5–10	–40	I.E. or M.E. Degree
608	Elect. Controls	Mass.		Production Engineer	6.5– 8.5	2–3	25–35	I.E. Deg. with Electronic or Prec. Mech. Assy. Exp.
609	Research & Devel.	Md.		30, 40, 42		8–		B.S.I.E.
610	Research & Devel.	Md.		30		5–		B.S.I.E.
611	Research & Devel.	Md.		30		3–		B.S.I.E.
612	Bearings	Mich.		10, 22, 42, 91	8.5–10.0	10–	30–40	I.E. or Bus. Deg. Pref.
613	Electronics	Utah		10–18, 34, 36, 40–46, 81, 91	7.5– 9.0	5–10	30–40	I.E. Degree
614	Electronic	Iowa		10, 30, 42, 92	7.5–10.0	5–10		I.E., M.E. or E.E. Deg.
615	Heat Trans. Equip. Mfg.	Wis.		11, 14, 15, 19, 32, 38	6.6–	3–	–35	B.S.I.E. Pref.
616	Elect. Mech. Instr.	Iowa		92	10.0–13.0			B.S.I.E.
617	Steel Goods Mfg.	N.M.		11, 31, 35, 54, 70	6.0– 8.0	3–5		I.E. Degree
618	Metalworking	Ohio		10, 11, 19, 32	Open	8		B.S.I.E.
619	Metal Casting & Machy.	Minn.		10, 30, 40, 44, 92	9.0–12.0	8–		B.S.M.E.
620	Food Machy. Mfg.	Iowa		36, 42, 43	6.0– 8.0	5–		M.E. Deg. or 2–3 Yrs. Col.
621	Boats	Mich.		30, 40	6.0– 8.4			
622	Casing Testers	Texas		30, 71		3–5	–35	B.S.I.E.
623	Semiconductors	Mass.		11, 13, 16, 19, 42	8.0–11.0	3–5		
624	Navy	D.C.		44, 49, 54, 70	4.5– 7.5		Open	
625	Storage Components	Ind.		11, 21, 28, 37, 38, 42	10.0–	5–10		I.E. Degree
626	Mining, Milling, Smelting	Utah		92, 13, 21	7.9–10.7	5–		Engineering Degree
627	Railroad	Md.		11, 35, 36, 38, 54, 70–73	6.5–10.0	3–	25–	College Graduate
628	Paper & Pulp Mfg.	Maine		11, 18, 22, 43, 91	8.0– 9.0	5–	–40	I.E. Degree
629	Electronics			50–55				I.E. or Bus. Ad. Grad. Major in Math.
630	Textile & Paper Prod.	Tenn.		10, 11, 13–15, 18, 19, 21 22, 26, 36	6.0– 7.5	2–3		I.E. Degree or Equiv.
631	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47, 90	7.5	3	20–	B.S. in Engineering
632	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	7.5	3	20–	B.S. in Engineering
633	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	6.2	2	20–	B.S. in Engineering
634	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	4.9	0	20–	B.S. in Engineering
635	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	5.8	1	20–	B.S. in Engineering
636	Air Force (Maint.)	Pa.		10, 11, 13–16, 18, 30–34, 39–47	6.2	2	20–	B.S. in Engineering
637	Glass	N.Y.		11, 13, 18, 21, 26, 31, 36, 42, 43	9.0–10.0	5–10		
638	Alum. & Chem.	La.		11, 13, 36, 38, 91	9.0–11.0	5–		I.E., I.M., or M.E. Grad.
639	Education	N.Y.		10, 30, 40, 50, 60	9.0–12.0	5–15		Ph.D. in I.E.
640	Athletic Equip.	Ohio		11, 13, 16, 19, 26, 32–34, 42, 44	8.4–	5–6	30–40	MTM required
641	Athletic Equip.	Ohio		11, 13, 16, 32, 42	6.5–	3–4	25–45	MTM required
642	Rubber (Ind. Prod.)	Mass.		10, 11, 13–15, 20–22, 32, 36, 38, 43, 42	Open	3–7	25–40	College Graduate
643	Pharmaceutical	Ind.		10, 11, 13–15, 18, 19, 42, 43, 53	5.7– 6.5	0–3		I.E. or M.E.
644	Electronics	Dela.		11, 18, 30–38, 42	Open		Open	I.E. with some M.E.
645	Management Cons.	Minn.		13, 31, 37, 43, 53, 55, 71, 72, 91	11.0–	5–	29–45	Engineering Degree
646	Steel Mfg. & Fabr.	Ala.		30	Open	5–	28–45	Exp. in Fabrication of Structural Steel
647	Printing	Eastern U.S.		30	Open		30–45	B.S. in I.E. or Equiv.
648	Chemical	Ill.		91	7.5– 8.0	4–5	25–30	
649	Bldg. Materials	N.Y.	30	10, 30, 35	15.0–			

* The above 3 P# have openings in New York City, Detroit, Mich., Syracuse, N. Y., Indianapolis, Ind., and Cleveland, Ohio

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement
12	Suggestion Systems
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organisation Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

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